FOCUSED FEASIBILITY STUDY REPORT SITE 3

Former Cedar Chemical Facility
Helena – West Helena, Arkansas
EPA ID No. ARD990660649

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June 2009

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LIST OF ACRONYMS

^{o}F	Fahrenheit
ADEQ	Arkansas Department of Environmental Quality
ARARs	Applicable or Relevant and Appropriate Requirements
bgs	below ground surface
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CAO	Consent Administrative Order
COC	Contaminant of Concern
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DO	Dissolved Oxygen
F&T	Fate and Transport
FI	Facility Investigation
FR	Federal Register
FS	Feasibility Study
ft	Feet
ft^2	Square Feet
ft^3	Cubic Feet
GRA	General Response Action
HELP	Hydrologic Evaluation of Landfill Performance
Koc	Organic Carbon Adsorption Coefficient
MCL	Maximum Contamination Level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	Milliliters per Gram
MSL	Medium-Specific Screening Level
NCDC	National Climatic Data Center
NCP	National Oil and Hazardous Substances Contingency Plan
NPDES	National Pollution Discharge Elimination System
O&M	Operation and Maintenance
ORP	Oxidation-Reduction Potential
PPE	Personal Protective Equipment

LIST OF ACRONYMS (Continued)

RAOs	Remedial Actions
RCRA	Resource Conservation and Recovery Act
RGOs	Remedial Goal Options
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SI	Site Investigation
SSL	Soil Screening Level
SVOCs	Semi-Volatile Organic Compounds
TBC	to-be-considered
ug/L	microgram per liter
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
yd^3	Cubic Yards

CERTIFICATION PAGE
FOCUSED FEASIBILTY STUDY – SITE 3
FORMER CEDAR CHEMICAL FACILITY
HELENA – WEST HELENA, ARKANSAS

I certify that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to evaluate the information submitted. I certify that the information contained in or accompanying this submittal is true, accurate, and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person (s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

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EXECUTIVE SUMMARY

This focused Feasibility Study (FS) Report has been prepared to evaluate alternatives for remedial action for dinoseb in subsurface soils at Site 3 in accordance with *Wormald Separate Agreement Pursuant to Consent Administrative Order LIS No. 07-027 for the Conduct of a Site Investigation and Feasibility Study* dated January 9, 2009 (Wormald Separate Agreement) between the Arkansas Department of Environmental Quality (ADEQ), and Ansul Incorporated, the predecessor to Wormald U.S., Inc. Specifically, the purpose of the FS is to:

- Develop remedial action objectives (RAOs) as identified in Wormald's Site Investigation (SI) Report (AECOM, May 2009) for dinoseb-impacted soils at Site 3;
- Identify and screen technologies considered applicable to the Site-specific conditions for such soils at Site 3; and
- Develop and perform a detailed analysis and comparison of appropriate remediation alternatives for such soils.

The data reviewed during the preparation of this focused FS is summarized in this Executive Summary, along with the description and evaluation of proposed remedies.

Scope of the Focused Feasibility Study

The scope of the focused FS presented in this document is limited to subsurface soil with residual dinoseb concentrations at Site 3. More specifically, this FS has been prepared to address the area investigated during the Wormald Site Investigation (AECOM, 2009) in accordance with Section 5F of the Wormald Separate Agreement (ADEQ, January 9, 2009).

Site 3 Description

The former Cedar Chemicals Facility ("Facility") is located to the south of the city of Helena-West Helena, in Phillips County, Arkansas. The Facility consists of 48 acres within the Helena-West Helena Industrial Park, approximately 1.25 miles southwest of the intersection of U.S. Highway 49 and State Highway 242. The Facility is bordered by farmland, State Highway 242, a rail spur, and industrial park properties. The current land use designation for the Facility is industrial and the property is expected to remain industrial (ADEQ, 2005). The former operational portion of the property is divided into two major areas: (1) the abandoned manufacturing area (approximately 40 acres) and (2) the wastewater treatment system area which is located on the south side of Industrial Park Road.

Site 3, the focus of this FS, is south of the main production area and includes the ditches and surrounding soil for the Facility's storm water drainage system. Storm water is reported to have flowed from the manufacturing area via sheet flow toward the south and to the storm water ditches within Site 3.

Conceptual Site Model Summary

During the Facility Investigation (FI) (EnSafe, Inc., 1996), the reported dinoseb concentration from the 4-8 foot sample in soil boring location 3SB-6 (13,000 milligrams per kilogram [mg/kg]; collected from lithologic boring 3LB-6) exceeded the United States Environmental Protection Agency (USEPA) Region 6 medium-specific screening level (MSL) for dinoseb in industrial soil. Dinoseb was then identified as a contaminant of concern (COC) for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001) and the Risk Evaluation (ADEQ, 2005). Dinoseb was the only COC identified for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001), but was not identified as a COC for Site 3 sediment, surface soil, or groundwater.

Five soil borings (TSB-1 through TSB-5) were installed within Site 3 during the Wormald SI (AECOM, 2009). The soil borings were installed for the collection of soil samples to investigate and confirm the historic detection of dinoseb reported in the 4-8 foot sample from 3SB-6 (EnSafe Inc., 1996). Dinoseb was reported in all samples at concentrations ranging from 31.3 mg/kg in TSB-2 to 80.4 mg/kg at TSB-3 (AECOM, 2009). All results were significantly below the USEPA Region 6 MSL for dinoseb in industrial soil (620 mg/kg); however, the soil samples exceeded the USEPA Region 6 maximum contaminant level (MCL)-based soil screening level (SSL) (5.10E-02 mg/kg).

Historic and current soil sample results were considered in the fate and transport analysis for dinoseb at Site 3. Based on the over 99 percent reduction in the concentration of dinoseb in subsurface soils since 1996, a half-life for dinoseb in soil at Site 3 (approximately 630 days) was calculated. The data indicate natural attenuation mechanisms are acting to reduce the concentration of dinoseb in subsurface soil at Site 3.

Fate and transport modeling was performed using SESOIL (Bonazountas and Wagner, 1981, 1984) and AT123D (Yeh, 1981) to simulate leaching of contaminants from the vadose zone and migration into the alluvial aquifer beneath the Site 3. Model simulations included Site-specific physical and chemical parameters and were made with and without degradation to provide a conservative range of predictions. Input dinoseb concentrations in soil ranged from two orders of magnitude less than concentrations reported in 2009 to three orders of magnitude greater than reported in 1996. Model results predict that residual dinoseb concentrations in subsurface soil at Site 3 do not pose a risk to potential down-gradient alluvial aquifer receptors. Model predictions are corroborated by results from groundwater samples collected from alluvial aquifer monitoring wells down-gradient of Site 3. Dinoseb values in these wells have been very low to non-detect in all samples collected between 1993 and 2008.

Risk-Based Remedial Goal Options (RGOs)

Site-specific risk-based RGOs were calculated to evaluate likely pathways for human exposure to dinoseb at Site 3. These pathways include:

- Exposure to dinoseb in soil by an on-Site construction worker during digging or excavation,
- Migration of dinoseb in soil to perched zone groundwater where it could be contacted by an on-Site construction worker during digging or excavation,
- Migration of dinoseb in soil to alluvial aquifer groundwater and exposure of an off-Site agricultural worker during crop irrigation, and
- Migration of dinoseb in soil to alluvial aquifer groundwater and exposure of an off-Site resident using groundwater as potable water.

The Site-specific risk-based RGOs for dinoseb in soil at Site 3 were calculated using a simplistic dilution attenuation factor (DAF), which was calculated using the Soil Screening Guidance (USEPA, 2002). The DAF calculated using this method does not account for the distance from the Site 3 of the potential down-gradient alluvial aquifer receptors and, as such, the risk-based RGOs conservative values that overestimate the potential for exposure and related risk.

The risk-based RGOs for Site 3 based on these pathways are summarized below.

Risk-Based RGOs for Dinoseb in Soil at Site 3

Land Use/Receptor	Dinoseb Concentration in Soil (mg/kg)	
	Direct Contact	Protection of Groundwater
Industrial (On-Site Construction Worker)[1]	739	11
Off-Site Agricultural Worker[2]	NA	294
Off-Site Resident[3]	NA	1.5

NOTES:

[1.] The direct contact RGO (on-Site construction worker receptor) is based on the potential exposure of the future construction worker to subsurface soil at Site 3. The protection of groundwater RGO (on-Site construction worker receptor) is based on potential exposure of the future construction worker to perched zone water during construction activities.

[2] The protection of groundwater RGO (off-Site agricultural worker receptor) is based on potential exposure of an agricultural worker to alluvial aquifer groundwater from an off-Site agricultural well.
[3] The protection of groundwater RGO (off-Site resident receptor) is based on potential exposure of a resident to alluvial aquifer groundwater from a potable water well.
NA = not applicable

Summary of Remedial Goals and Area Requiring Remediation

The soil to groundwater RGO for dinoseb was calculated to be 1.5 mg/kg based on potential exposure of an off-Site resident to alluvial aquifer water from a potable well. Although model simulations and groundwater sampling results indicate residual dinoseb concentrations in soil at Site 3 do not pose a risk to down-gradient receptors of alluvial aquifer groundwater, this value (1.5 mg/kg) was adopted as the Site-specific cleanup level in this FS.

Based on the cleanup level, the residual concentrations of dinoseb in subsurface soil measured in March 2009 (AECOM, May 2009), the formula presented in equation 3-1 of Section 3.7.1, and the Site-specific calculated degradation rate (0.0011/day), it is estimated that natural attenuation mechanisms will reduce residual dinoseb concentrations to below the cleanup level in approximately 10 years.

The estimated soil area requiring remedial action at Site 3 is approximately 0.26 acres or approximately 11,306 square ft (ft^2). Using an approximate depth of impacted soil of 4 – 8 feet below ground surface (ft bgs), the estimated volume of soil is 45,224 cubic feet (ft^3) or 1,675 cubic yards (yd^3).

Identification and Selection of Remedial Alternatives

Four remedial alternatives were identified and retained for dinoseb in subsurface soil at Site 3 in this FS:

1. Alternative 1 - no action;
2. Alternative 2 - institutional controls;
3. Alternative 3 - institutional controls and down-gradient groundwater monitoring, and
4. Alternative 4 - engineered barrier with institutional controls and down-gradient groundwater monitoring.

A detailed analysis of the aforementioned remediation alternatives was performed using the nine evaluation criteria outlined in Title 40 of the Code of Federal Regulations (CFR) Part 300.430(e)(9)(iii) to form the basis for selecting a final Site remedy. A summary of the evaluation results is presented in Table ES-1. Based on the detailed evaluation of these alternatives performed as part of this focused FS, Alternative 2 – Institutional Controls – was selected as the preferred remedy.

Rationale for the Selected Remedy

Alternative 2 meets the objective of reducing risk to on-Site workers, future on-Site construction workers, and trespassers through the use of Institutional Controls. Soil concentrations will be reduced over time by natural attenuation mechanisms. A summary of the Site-specific data considered during the evaluation and selection process is provided below.

- Site 3 is comprised of 3 storm water ditches and surrounding soils south of the main production area of the Facility. No process units existed at Site 3 and there were no documented manufacturing activities conducted in this area.
- During the FI (EnSafe, Inc., 1996), the reported dinoseb concentrations from five soil samples collected from Site 3 ranged from 0.63 mg/kg to 13,000 mg/kg. The concentration of dinoseb in one soil sample collected from the 4-8 ft depth interval of soil boring location 3SB-6 (13,000 mg/kg) exceeded the EPA Region 6 MSL for dinoseb in industrial soil. Dinoseb was subsequently identified as a COC for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001).
- Sediment samples collected during the FI (EnSafe, Inc., 1996) were predominantly non-detect for dinoseb. Furthermore, dinoseb was not selected as a COC for sediment or groundwater at Site 3 (EnSafe, Inc., 2001; ADEQ, 2005) and does not pose a risk to human health and the environment for these media.
- Confirmation sampling was performed at historical sample location 3SB-6 to assess the current concentration of dinoseb in subsurface soil (AECOM, May 2009). Dinoseb concentrations ranged from 30 mg/kg to 80 mg/kg in the five soil samples collected; this concentration range is three orders of magnitude lower (99% reduction) than the historic concentration, 13,000 mg/kg, reported in sample 3SB-6 (4-8 ft bgs).
- All concentrations of dinoseb detected in subsurface soil during the 2009 Wormald SI (AECOM, May 2009) were less than:
    - The EPA Region 6 MSL for dinoseb in industrial soil (620 mg/kg);
    - The Site-Specific risk-based RGO calculated for potential future construction worker exposure to subsurface soil at Site 3 (739 mg/kg); and
    - The Site-specific risk-based RGO calculated for potential agricultural worker exposure to alluvial aquifer groundwater (294 mg/kg).
- The only RGOs exceeded were the Site-specific risk-based RGO for potential future construction worker exposure to perched zone water (11 mg/kg) and the Site-specific risk-based RGO for potential resident exposure to alluvial aquifer groundwater (1.5 mg/kg).

- Literature values for the half-life of dinoseb in soil range from 30 days to 123 days (see Section 3.7.1 of this FS). Based on Site-specific physical and chemical characteristics of subsurface soil at Site 3, a Site-specific half-life of approximately 630 days (degradation rate of 0.0011/day) was calculated. This Site-specific half-life is more conservative than literature values cited above.

- Site-specific physical and chemical properties were used to model the fate and transport of dinoseb in subsurface soil at Site 3 and evaluate the potential of residual dinoseb concentrations to leach into groundwater beneath the Site. Model simulations were performed with and without the inclusion of degradation to evaluate potential migration under the most conservative assumptions.

- The model was run with soil concentrations three orders of magnitude greater than the highest historic dinoseb concentration detected at Site 3 (13,000 mg/kg in historic soil sample 3SB-6). Using the Site-specific half-life for dinoseb in soil (630 days), model results predict that concentrations of dinoseb in alluvial aquifer groundwater will not exceed the MCL (7 microgram per liter [ug/L]) at the property boundary (the exposure point for residential and agricultural use). Model simulation without degradation using 2009 soil quality data also indicate that concentrations of dinoseb in alluvial aquifer groundwater will not exceed the MCL at the property boundary, indicating no risk from dinoseb to potential off-Site groundwater receptors.

- Concentrations of dinoseb in alluvial aquifer groundwater have not exceeded the MCL in monitoring wells down-gradient of Site 3 in any sample collected over a period of 15 years between 1993 and 2008 (Table 3-4).

- The present worth life-cycle costs associated with alternatives 3 and 4 are more than those associated with alternative 2. Since all four alternatives rely on natural attenuation mechanisms to reduce soil concentrations over time, the expected time to reach the Site-specific clean-up goal is the same for all four alternatives; and, as such, there is no measurable or increased benefit to protection of human health or the environment by implementing the more costly alternatives 3 and 4.

Based on the information presented above, the residual concentration of dinoseb in subsurface soil at Site 3 does not pose a current or future risk to off-Site receptors of alluvial aquifer groundwater. Therefore, the only remaining risk from residual dinoseb in subsurface soil at Site 3 is the risk of potential exposure of future construction workers to perched zone water. Alternative 2 – Institutional Controls – is an appropriate and cost-effective remedial alternative for residual dinoseb concentrations in subsurface soil at Site 3. Furthermore, Site-specific soil quality data indicate that residual dinoseb concentrations in subsurface soil at Site 3 will continue to be reduced naturally over a relative short period of time through natural attenuation processes occurring at the Site. Alternative 2 is the preferred remedial alternative for dinoseb in subsurface soil at Site 3 to protect human health and the environment in accordance with the

National Oil and Hazardous Substance Contingency Plan (NCP) of November 20, 1985 (50 FR 47973) and the amended NCP of March 5, 1990 (55 FR 8666).

1.0 INTRODUCTION

1.1 FEASIBILITY STUDY OBJECTIVES

This focused Feasibility Study (FS) Report has been prepared to evaluate alternatives for remedial action for Site 3 in accordance with *Wormald Separate Agreement Pursuant to Consent Administrative Order LIS No. 07-027 for the Conduct of a Site Investigation and Feasibility Study* (Wormald Separate Agreement) between the Arkansas Department of Environmental Quality (ADEQ), and Ansul Incorporated, the predecessor to Wormald U.S., Inc, dated January 9, 2009. Specifically, the purpose of the FS is to develop remedial action objectives (RAOs) as identified in Wormald's Site Investigation (SI) Report (AECOM, May 2009) for dinoseb-impacted soils at Site 3; identify and screen technologies considered applicable to the Site-specific conditions for such soils at Site 3; and develop and perform a detailed analysis and comparison of appropriate remediation alternatives for such soils. The approach adopted to achieve these objectives is outlined below.

1.2 REPORT ORGANIZATION

Although this is not a Comprehensive Environmental Response Compensation and Liability Act (CERCLA; "Superfund") regulated Site, the FS process was completed using United States Environmental Protection Agency (USEPA) guidance. As such, this FS has been prepared in accordance with CERCLA guidance as promulgated under the National Oil and Hazardous Substances Contingency Plan (NCP) of November 20, 1985 (50 Federal Register [FR] 47973), the Superfund Amendments and Reauthorization Act (SARA) of October 17, 1986, and the amended NCP of March 5, 1990 (55 FR 8666). The general framework of this FS is based on the USEPA document, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, October 1988).

The basic steps in the FS process and, consequently, the organization of this FS report are as follows:

- Summarize the results of the remedial investigation (RI), including the risk assessment (Section 2.0);
- Summarize the Conceptual Site Model (CSM), include geology, hydrogeology, nature and extent of dinoseb at Site 3, and dinoseb fate and transport in relation to Site 3 (Section 3.0);
- Identify media of concern (Section 4.0);
- Determine RAOs for the media of concern (Section 4.0);
- Identify general response actions (GRAs) to meet RAOs (Section 4.0);
- Identify and screen technologies based on effectiveness, implementability, and cost (Section 5.0);

- Develop and evaluate potential remediation alternatives based on NCP criteria (Section 6.0);
- Conduct a comparative analysis of the potential remediation alternatives (Section 6.0); and
- References used to prepare this focused FS Report are listed in Section 7.0.

2.0 FACILITY BACKGROUND

This section presents the Facility background information relevant to the focused FS for Site 3. Information is summarized from the Facility Investigation (FI) Reports (EnSafe, Inc., 1996; AMEC Geomatrix, February 2009), the Current Conditions Report (Geomatrix, November 2007), and the Wormald SI Report (AECOM, May 2009). Appendix A contains a list of key documents reviewed during the preparation of this FS.

2.1 SITE DESCRIPTION AND LOCATION

The Former Cedar Chemical Facility ("Facility") is located to the south of the city of Helena-West Helena, in Phillips County, Arkansas. The Facility consists of 48 acres within the Helena-West Helena Industrial Park, approximately 1.25 miles southwest of the intersection of U.S. Highway 49 and State Highway 242. A Site location map is included as Figure 2-1. The Facility is bordered by farmland, State Highway 242, a rail spur, and industrial park properties as shown on Figure 2-2. The former operational portion of the property is divided into two major areas: (1) the abandoned manufacturing area and (2) the wastewater treatment system area which is located on the south side of Industrial Park Road. Of the 48 acres, approximately 40 acres comprise the abandoned manufacturing area of the Facility, which is fenced. The current wastewater treatment ponds are located on an additional eight acres of the property. An undeveloped wooded area west of the wastewater treatment ponds and south of Industrial Park Road is part of the Site, but does not appear to have been historically part of the manufacturing facility.

Site 3 includes a grassy area and surrounding storm water ditches located northeast of Industrial Park Road across from the wastewater treatment ponds (see Figure 2-2).

2.2 HISTORIC FACILITY OPERATIONS

Prior to 1970, the land where the Site now exists was used for agricultural purposes (EnSafe, Inc, 1996). The plant was constructed and initially operated by Helena Chemical. The construction date of the Facility is not documented in available records; however, several reports state that operations began at the Site around 1970 with the manufacture of propanil. In 1971, the plant was sold to Mr. Jerry Williams, who in turn formed Eagle River Chemical Corporation ("Eagle River") where he and Ansul became owners. Dinoseb production subsequently began at the Site in 1972. In 1973, Mr. Williams purchased all of Ansul's shares in Eagle River and became sole owner of Eagle River. Dinoseb production at the Facility ceased shortly thereafter. Methoxychlor and other agricultural chemicals were then produced at the Site. The plant subsequently operated under the name Vertac, Inc. In 1986, the plant was sold to Cedar Chemical Corporation ("Cedar Chemical"; Geomatrix, November 2007).

During its operational life until Cedar Chemical declared bankruptcy and ceased operations at the Site in March 2002, the Facility manufactured various and different agricultural chemicals, including insecticides, herbicides, polymers, and organic intermediates. Plant processes were batch operations, with seasonal production fluctuations and the frequent introduction of new products. The plant also produced a variety of chemicals on a toll manufacturing basis for a number of customers.

At the time directly prior to Cedar Chemical's bankruptcy, the Facility consisted of six production units:

- Unit 1 was utilized for formulation of various custom chemicals such as permethrin and permethrin acid chloride, for other companies.
- Unit 2 was the propanil production unit.
- Unit 3, known as the Expansion Area, was destroyed in a fire and explosion on September 26, 1989.
- Unit 4 was used for production of various custom products such as orfom D-8 and orfom CO300.
- Unit 4 was also contracted from time to time for the production of methyl 2-benzamide carbonate (MBC) and methyl ethyl sulfide (MES) and the mixing of metam sodium.
- Unit 5 was primarily used to manufacture nitroparaffin derivatives.
- Unit 6 began producing dichloroaniline in 1991 used in the production of Propanil.

The chemicals identified in this bulleted list are not an exhaustive list; many other chemicals were produced at the Facility after 1973. The unit(s) involved in the production of these chemicals could not be identified with certainty.

Site 3, the focus of this FS, includes the ditches and surrounding soil for the Facility's storm water drainage system. Storm water is reported to have flowed from the manufacturing area via sheet flow toward the south and to the storm water ditches within Site 3. Site 3 is south of the main production area and the area between the storm water ditches is predominantly undeveloped (Figure 2-2).

2.3 SUMMARY OF REMEDIAL INVESTIGATION

In 1991, Cedar Chemical entered into Consent Administrative Order (CAO) No. LIS 91-118 requiring the completion of a FI at the Site. Phases I, II, and III of the FI were performed by EnSafe, Inc. in 1993 through 1996 (EnSafe, Inc., 1996). The FI results were then incorporated into a risk assessment in 2001, and submitted with a final addendum to ADEQ in 2002 prior to the operational shutdown of the Facility (EnSafe, Inc., 2001; 2002).

Groundwater and soil sampling was conducted at the Facility in Phase I of the FI to assess the nature and extent of contamination. No additional wells were installed during Phase I of the FI at Site 3. A total of ten (10) surface soil and sediment samples (3SED-1 through 3SED-10) were collected from the drainage ditches and storm water pond associated with this Site. Nine samples (3SED-1through 3SED-9) were collected within the storm water ditches. Sample 3SED-10 was sampled adjacent to the storm water pond. All Site 3 sediment samples were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, and Resource Conservation and Recovery Act (RCRA) metals to evaluate whether storm water runoff had impacted the ditches (EnSafe, Inc., 1996). Elevated levels of metals and pesticides were detected in the sediment samples collected during Phase I investigations.

Additional soil sampling was conducted at Site 3 during Phase II of the FI to verify results from Phase I sampling. No additional groundwater sampling was performed. To assess whether the elevated levels of metals and pesticides were confined to the sediment or if they were also present in the native soils, thirteen (13) locations (3SED-11 through 3SED-23) were sampled at two depth intervals. These soil samples were analyzed for constituents detected during the Phase I investigation (EnSafe, Inc., 1996). Phase II soil sample results indicated that very few contaminants had migrated into the subsurface soil. To aid in mapping the clay semi-confining unit in the area, one lithologic boring (3LB-6) was also advanced. Due to heavy staining observed from 3 to 7 feet (ft), three soil samples were collected from the boring and analyzed for SVOCs (EnSafe, Inc., 1996).

Additional soil sampling was conducted at Site 3 during Phase III of the FI to verify results from Phase II sampling; but no additional groundwater sampling was performed. On soil boring was installed 25 ft northwest of boring 3LB-6 to assess the vertical migration of dinoseb detected in the Phase II samples.

During the FI (EnSafe, Inc., 1996), the reported dinoseb concentration from the 4-8 ft sample in soil boring location 3SB-6 (13,000 mg/kg; collected from lithologic boring 3LB-6) exceeded the EPA Region 6 medium-specific screening level (MSL) for dinoseb in industrial soil. Dinoseb was then identified as a contaminant of concern (COC) for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001) and the Risk Evaluation (ADEQ, 2005). Dinoseb was the only COC identified for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001), but was not identified as a COC for Site 3 sediment, surface soil, or groundwater.

In March 2007, ADEQ issued Consent Administrative Order LIS No. 07-027.to Wormald, USA, Inc., successor to Ansul, Inc., Helena Chemical Company Inc., and ExxonMobil Chemical Company successor to Mobil Chemical Co. AMEC Geomatrix conducted additional FI work at the Facility in 2008 on behalf of Helena Chemical Company Inc. and ExxonMobil Chemical Company (AMEC Geomatrix, February 2009). No additional investigation activities were performed at Site 3 as part of the AMEC Geomatrix 2008 FI.

Wormald, USA Inc. subsequently entered into *Wormald Separate Agreement Pursuant to Consent Administrative Order LIS No. 07-027 for the Conduct of a Site Investigation and Feasibility Study* (Effective Date January 9, 2009; Wormald Separate Agreement), which is the basis for the Wormald SI (AECOM, May 2009) performed at Site 3 in March 2009 and this FS.

The Wormald SI, conducted in March 2009, focused on the collection of additional subsurface soil samples at Site 3 to investigate the concentration of dinoseb in subsurface soil at historic sample location 3SB-6 and to evaluate possible dinoseb concentrations in the vicinity of 3SB-6. (See Section 3.5 for a summary of the SI findings). This FS has been prepared for the area investigated during the Wormald SI – Site 3 dinoseb in subsurface soil - pursuant to the Wormald Separate Agreement (ADEQ, January 2009).

3.0 CONCEPTUAL SITE MODEL

3.1 FACILITY GEOLOGY

The general stratigraphic succession beneath the Facility from surface to depth comprises surface soil and loess within fluvial alluvium, fluvial alluvium aquifer deposits (coarsening downward), the Jackson Clay Group, and Sparta Sand. A 1996 FI Report identified five stratigraphic units within the Quaternary alluvium at the Facility (EnSafe, Inc., 1996). In general, the findings of the 2008 FI (AMEC Geomatrix, February 2009) are in agreement with these units; modifications to these units based on the 2008 FI are included in the descriptions below.

- Unit 1 was reported to extend from ground surface to approximately 32 ft below ground surface (bgs) and consists of silts, clays, and sands (EnSafe Inc., 1996). In the 2009 FI Report (AMEC Geomatrix, 2009), this unit is reported to extend from ground surface to 30 to 40 ft bgs. Unit 1 includes a perched groundwater-bearing zone referred to as the Perched Zone.
- Unit 2 extends from approximately 30 to 45 ft bgs, and consists of clays and silts. Unit 2 is referred to as the semi-confining unit. The thickness of this unit varies across the Facility. (NOTE – this unit was grouped with Unit 1 in the 2009 FI Report (AMEC Geomatrix, 2009).
- Unit 3 was reported to extend from 47 to 116 ft bgs in the FI (EnSafe, Inc., 1996) and to consist of coarsening downward sand and gravel with occasional clay stringers. Based on the 2008 FI (AMEC Geomatrix, February 2009), this unit extends from approximately 45 to 70 ft bgs and consists of fine-grained sand with inter-bedded gravel layers. Unit 3 corresponds to the upper portion of the alluvial aquifer.
- Unit 4 was reported to extend from 116 to 131 ft bgs, and to consist of clay (EnSafe, Inc., 1996). Based on the 2008 FI (AMEC Geomatrix, February 2009), this unit extends from approximately 70 to 130 ft bgs, consists of fine to medium sand and exhibits some coarsening downward with depth. Unit 4 is the middle section of the alluvial aquifer.
- Unit 5 was reported to extend from 131 to 152 ft bgs, and consists of sand and gravel (EnSafe, Inc., 1996). Based on the 2008 FI (AMEC Geomatrix, February 2009), this unit extends from approximately 130 to 150 ft bgs and consists of medium to coarse sands with inter-bedded layers of gravel and cobbles. Unit 5 is the lower section of the alluvial aquifer, and overlies the regional confining layer (Jackson clay).

3.2 FACILITY HYDROGEOLOGY

The Facility is underlain by unconsolidated Quaternary and Tertiary age sedimentary deposits. Two aquifer regimes exist at the Facility: a discontinuous perched zone in the silt and clay surficial sediments (ground surface to approximately 30 to 40 ft bgs) and the alluvial aquifer. The alluvial aquifer, as discussed above, consists of an upper unit at approximately 45 to 70 ft bgs, a middle unit at approximately 70 to 130 ft bgs, and a lower unit at approximately 130 to 150 ft bgs. The perched zone and the alluvial aquifer are separated by a silty clay stratum that is reported to have a variable thickness across the Facility property. Locally, the alluvial aquifer appears to be confined by the upper 45 ft of silt and clay.

The alluvial aquifer overlies the Jackson-Claiborne Group stratum of clay and lignite materials at approximately 150 ft bgs. The Jackson Clay is the basal confining unit for the alluvial aquifer in this region of Arkansas (EnSafe, Inc., 1996). All groundwater at the Facility has been classified by ADEQ as Class 1 under the USEPA Guidelines for Groundwater Classification under EPA Groundwater Protection Strategy (November 1986). Class 1 groundwater is defined by the USEPA as “special groundwater usually of high value and irreplaceable sources of drinking water and/or ecologically vital.”

3.3 FACILITY SURFACE WATER HYDROLOGY

The Facility is located approximately 3.5 miles west of the Mississippi River, in part of a physiographic province and setting known as the Mississippi Embayment Region of the Gulf Coastal Plain. The embayment is separable into two general physiographic areas, the lowland of the Mississippi River Valley alluvial plain and the Coastal Plain uplands (Geomatrix, November 2007). The Mississippi River Valley alluvial plain lies along the Mississippi River and covers the eastern third of Arkansas. The Facility lies within the alluvial plain, although it is reportedly not within the 100-year floodplain of the Mississippi River.

The topography of the terrain at the Facility and surrounding area is relatively flat, with some areas sloping gently toward the southeast. The Facility is located on a gentle drainage divide. To the north and west, regional surface water flow is generally southwest, connecting through a series of ditches, creeks, and bayous to the White River approximately 50 miles to the southwest. To the south and east, regional surface water flow is generally toward the Mississippi River.

Storm water at the Facility has historically been collected in a series of surface ditches, which flow to a storm water collection pond located at the southeast corner of the facility. After approximately the mid-1970s, storm water was pumped from this pond via an underground pipe to the Facility’s wastewater treatment ponds south of Industrial Park Road. From there, the water was diverted to Outfall 001where it was discharged under National Pollutant Discharge Elimination System (NPDES) Permit AR0036312. In addition, it is reported that the effluent from the wastewater treatment system was pumped through a 4.5-mile pipeline and discharged directly into the Mississippi River from Outfall 002 under the same NPDES permit.

3.4 METEOROLOGY

Arkansas has a mild climate with long spring and fall seasons. Based on data collected from Helena , Arkansas between 1971 and 2000, the average temperatures in January range from 29.8 to 48.9 degrees Fahrenheit (^{o}F)with a mean January temperature of 39.4 ^{o}F; the average temperatures in July range from 71.9 ^{o}F to 93.0 ^{o}F with a mean July temperature of 82.5 ^{o}F. (National Climatic Data Center (NCDC), February 2004). The annual relative humidity in Arkansas averages 57% (www.netstate.com). Helena, Arkansas receives approximately 54 inches of rainfall annually (NCDC, February 2004).

3.5 FACILITY LAND USE

The land use of the facility property is currently industrial. The property land use is expected to remain industrial (ADEQ, 2005).

3.6 SUMMARY OF NATURE AND EXTENT OF DINOSEB AT SITE 3

Site 3 was investigated during the FI (EnSafe, Inc., 1996) and the 2009 SI (AECOM, May 2009). 1996 FI and 2009 SI dinoseb detections are summarized in Table 3-1, and sample locations are illustrated on Figures 3-1 and 3-2 for the 1996 FI and 2009 SI, respectively. A summary of the investigation results is provided in the paragraphs below.

During the 1996 FI, dinoseb was detected at concentrations ranging from 0.63 milligrams per kilogram (mg/kg) to 13,000 mg/kg in subsurface soil samples from Site 3. The highest concentration of dinoseb (13,000 mg/kg) was detected in subsurface soil sample 3SB-6 (4 to 8 ft bgs) (Figure 3-1). Dinoseb was subsequently identified as a COC for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001; ADEQ, 2005). The Wormald SI (March 2009) focused on the collection of additional subsurface soil samples at Site 3 to investigate and confirm the concentration of dinoseb in subsurface soil at historic sample location 3SB-6 and to evaluate soil quality related to dinoseb in the vicinity of 3SB-6.

Five soil borings (TSB-1 through TSB-5) were installed during the Wormald SI within Site 3 for the collection of soil samples for dinoseb analysis (Figure 3-2). Prior to soil boring installation, historic soil sample 3SB-6 was located and staked by Smith and Weiland Surveyors, an Arkansas licensed land surveyor, as the location for TSB-1 using survey coordinates extracted from the basemap along with

Figure 3 of the *Wormald Site Investigation Work Plan* (AECOM, January 2009). A 10 foot by 10 foot grid centered on TSB-1 was established by the surveyor and the locations for TSB-2 through TSB-5 were staked on this grid as proposed on Figure 3 of the *Wormald Investigation Work Plan*. A soil sample was collected from the 4 to 8 ft depth interval in each of the five borings for the dinoseb analysis. Dinoseb was reported in all samples at concentrations ranging from 31.3 mg/kg in TSB-2 to 80.4 mg/kg at TSB-3 (AECOM, May 2005). In accordance with ADEQ policy, 2009 SI results were compared to the screening levels that were in effect at the time of the SI work plan submittal. Screening levels used were the USEPA Region 6 MSL of 620 mg/kg and the USEPA Region 6 Maximum Contaminant Level (MCL)-based soil screening level (SSL) of 5.10E-02 mg/kg. All results were significantly below the USEPA Region 6 MSL for dinoseb in industrial soil (620 mg/kg); however, the soil samples exceeded the USEPA Region 6 MCL-based SSL (5.10E-02 mg/kg).

Confirmation sampling performed in March 2009 at TSB-1, which is co-located with historic soil sample 3SB-6, indicates that the dinoseb concentration of 13,000 mg/kg reported for 3SB-6 (at 4 – 8 ft bgs) in the FI (EnSafe, Inc., 1996) "is not representative of current Site 3 soil conditions" (AECOM, May 2009).

Based on these results, the assessment of residual dinoseb in subsurface soil at Site 3 is adequate to facilitate fate and transport analyses.

3.7 SUMMARY OF FATE AND TRANSPORT OF DINOSEB

At Site 3 of the Cedar Chemical Site, dinoseb was detected in subsurface soil and identified as a COC for subsurface soil only at Site 3 (EnSafe, Inc., 2001; ADEQ, 2005). This fate and transport evaluation considers mechanisms that may result in migration of dinoseb through soil at Site 3 to groundwater at the Cedar Chemical Facility and specifically, at Site 3. The physical and chemical parameters of dinoseb, Site-specific soil properties, and available literature are considered as part of this evaluation. Furthermore, numerical models were used to evaluate dinoseb fate and transport at Site 3 based on Site-specific soil and groundwater conditions and model results are presented in Appendix B.

3.7.1 Soil Migration Pathway

Dinoseb in soil may be degraded by abiotic volatilization or photodegradation or degraded through biodegradation. Migration through soil to subsurface soil or underlying groundwater is affected by dissolution and adsorption. Table 3-2 lists physical and chemical properties, such as solubility, organic carbon adsorption coefficient (Koc), and Henry's Law constant, that influence the transport of dinoseb through soils. Transport also depends on the Site-specific conditions (e.g., soil permeability, porosity, particle size distribution, organic carbon content).

Biodegradation of dinoseb can occur under aerobic or denitrifying conditions, although degradation is not complete (Stevens and others, 1991). Complete biodegradation is promoted by strongly reducing conditions (Roberts and others, 1996). The clayey soils and intermittent flooding that occur in parts of the Cedar Chemical Site, have the potential to promote reducing conditions.

Rates of dinoseb degradation are indicated by half-life calculations. Howard et al. (1991) reported half-life rates in soil ranging from 43 to 123 days and the estimated overall half-life in soil is 30 days (Howard, 1991). Literature values for the half-life of dinoseb under various are summarized in the table below for a range of conditions.

Estimated Half-Life	**Media**	**Conditions**	**Reference**
100 days	Soil	Vadose zone sandy loam, without volatilization	USEPA, 1996
26 days	Soil	Half-life due to volatilization from a soil surface	USEPA, 1996
14 hours	Soil	Sandy loam soil exposed to natural sunlight	Howard, 1991
4.1 days	Air	Half-life for reaction of vapor phase with photochemically generated hydroxyl radicals	Howard, 1991

In 1995, dinoseb was measured at 13,000 mg/kg at Site 3 boring 3SB-6 (4 to 8 ft bgs). By March 2009, concentrations in soil samples from borings TSB-1 through TSB-5, collected in the same area and at the same depth, averaged 52 mg/kg (AECOM, May 2009). This equates to a decrease of over 99 percent between 1995 and 2009. Based on this data, a Site-specific half-life and degradation were calculated using the equations below based on Faure, 1977:

$$C = C_o e^{-\lambda t} \qquad \text{(Equation 3-1)}$$

and

$$\lambda = \frac{\ln 2}{t_{1/2}} \qquad \text{(Equation 3-2)}$$

where t is the elapsed time, t (days); Co is the initial concentrations (mg/kg); C is the concentration at time, t (mg/kg); λ is the degradation rate (1/day); and $t^{1/2}$ is the half-life (days). A Site-specific half-life of approximately 630 days (degradation rate of 0.0011/day) was calculated based on data from Site 3 and equations 3-1 and 3-1 above. This relatively long half-life, compared to the prediction of 100 days (USEPA, 1996), may result from the clayey nature of the soil which may inhibit volatilization.

3.7.2 Soil-to-Groundwater Pathway

Partitioning between soil and groundwater is controlled by solubility and adsorption to soil components. Adsorption to organic matter in soil is defined by the Koc. For dinoseb, the Koc has been variously reported. Some examples of Koc values are 124 milliliters per gram (mL/g; Howard, 1991), 500 mL/g (Roberts and others, 1998), and 6607 mL/g (soil buffered at a pH of 3; Howard, 1991). In addition to adsorption to organic material, there is evidence that dinoseb can adsorb strongly to clay minerals, particularly at acidic pHs. Adsorption is affected by the type of clay mineral present. For example, the adsorption capacity of the clays for dinoseb is greater on montmorillonite than on kaolinite or illite and potassium- or ammonium-saturated clays are more sorptive than clays dominated by other ions (Haderlein and others, 1996). As described in Section 3.1 and based on boring logs from the FI (EnSafe, Inc., 1996) and the Wormald SI (AECOM, May 2009), soil from ground surface to approximately 45 ft bgs consists of predominantly clay and silt.

Adsorption has been reported to be inhibited by competitive adsorption of more soluble herbicides (Martins and Mermoud, 1998). The solubilities of propanil (225 milligrams per liter [mg/L]) and 3,4-dichloroaniline (580 mg/L) exceed that of dinoseb (52 mg/L). The competitive adsorption of these more soluble herbicides, which were produced for many years throughout the tenure of the Facility, has the potential to decrease dinoseb adsorption.

Dinoseb that is not adsorbed to soil may be transported through the soil column to groundwater. Its concentration will be limited by its solubility. Hydrolysis in water is not important and volatilization from water is expected to be slow (Howard, 1991). However, dinoseb in groundwater is subject to degradation. Biodegradation half-life rates vary from 246 days for unacclimated (freshly contaminated), aerobic conditions to 4 days in anaerobic groundwater (Howard et al, 1991). Based on almost uniform lack of detected nitrate in historic groundwater samples collected from monitoring wells at the Facility (Geomatrix, November 2007, Table 1), the potential for nitrate-reducing conditions exists in groundwater underlying the Facility.

3.7.3 Fate of Dinoseb

The primary destructive process in the subsurface is biodegradation, which is mediated by microorganisms. Therefore, the most important environmental parameters affecting dinoseb degradation are the presence of degradative microorganisms, which allow for biodegradation, the presence of nitrate in the soils, and adsorption of dinoseb to soil surfaces, which inhibits biodegradation (Stevens et al. 1990).

The potential for a chemical to biodegrade is affected by its toxicity to soil microorganisms, the composition and size of the soil microbial population, and physical and geochemical characteristics of its environment such as pH, dissolved oxygen (DO), redox potential (ORP), temperature, and moisture. The concentration of an organic chemical also affects the biodegradation rate. Biodegradation can decrease or completely stop at extremely low concentrations (i.e., not enough of a compound to propagate biodegradation) or extremely high concentrations (i.e., inhibition by toxicity at high concentrations). In clay soils, like those encountered at Site 3, toxicity effects are decreased because microorganism contact with dinoseb would be decreased (Martins and Mermoud, 1998).

In general, sorbed contaminants in soils are not available for microorganisms to degrade; however, once partitioned into the pore water aqueous phase, biodegradation can potentially take place. The reduction in soil concentrations of dinoseb since 1995 (Section 3.7.1) and the decrease in dinoseb groundwater concentrations at other areas of the Facility (AMEC Geomatrix, June 2009), indicate that natural attenuation mechanisms are working at the Site to decrease residual dinoseb concentrations.

3.7.4 Fate and Transport Modeling Using SESOIL and AT123D

In order to provide a more thorough evaluation of the fate and transport (F&T) of dinoseb in the environment, SESOIL (Bonazountas and Wagner, 1981, 1984) was used to model potential leachate concentrations in the underlying alluvial aquifer resulting from residual dinoseb in soil at Site 3. SESOIL was developed for USEPA Office of Water and Office of Toxic Substances and is an unsaturated zone F&T finite difference vertical transport model that is more complex than the USEPA SSL equations. Unlike the SSL equations, which assume an infinite source and a constant infiltration rate, SESOIL uses a three-dimensional user-defined source and can simulate a constant infiltration rate or an infiltration rate calculated based on location-specific weather variables (monthly rainfall averages) and Site-specific soil data. Furthermore, SESOIL simulates partitioning of the contaminant to volatile, adsorbed, and dissolved phases, with the dissolved portion traveling with infiltrating soil moisture based on soil properties. Degradation can also be simulated in the model.

SESOIL is a component of the SEVIEW© program (Environmental Software Consultants, Inc., 2006), a menu-driven, integrated contaminant modeling system that simplifies transport and fate modeling by linking SESOIL to the saturated zone model AT123D (Yeh, 1981), which simulates contaminant transport under one-dimensional groundwater flow. The concentration in leachate, derived from the SESOIL model, is used as input to the AT123D model to compute a resulting concentration in groundwater beneath the modeled location. The AT123D model is then used to predict resulting groundwater concentrations when pore water from the vadose zone mixes with water in the underlying aquifer. AT123D is an analytical groundwater transport model that computes the spatial-temporal concentration distribution of a constituent in the aquifer and predicts the transient spread of a chemical plume through an aquifer using advection, dispersion, adsorption, and decay. The decay function was not used in this model.

A detailed description of the inputs and procedures used to model potential leachate concentrations at Site 3 is provided in Appendix B. Several scenarios were modeled using SESOIL and AT123D to provide a range of results based on conservative and realistic assumptions. All scenarios included a 10 by 10 foot area from 4 to 8 ft bgs where dinoseb concentrations were applied in the model Scenarios considered two different hydraulic gradients and groundwater flow directions based on potentiometric maps for the alluvial aquifer in July 2008 (Figure 3-3) and September 2008 (Figure 3-4) presented in the FI Report (AMEC Geomatrix, February 2009). Simulations with and without degradation in soil were evaluated; in scenarios where degradation was included, the Site-specific calculated rate of 0.0011/day (see Section 3.7.1 of this FS) was used since it is more conservative than values reported in literature. Leachate concentration migrating to the alluvial aquifer groundwater was modeled directly beneath Site 3 and AT123D was used to simulate resulting groundwater concentrations in alluvial aquifer groundwater at the Facility property boundary. Since the Site is part of an industrial property and is expected to remain industrial, the property boundary is the reasonable point of compliance for the dermal and ingestion exposure scenarios for both the residential and agricultural worker population.

The maximum soil concentration that can be input into SESOIL is 5.4 grams per gram soil (5.41E+07 mg/kg), which is several orders of magnitude greater than detected dinoseb concentrations in current (AECOM, May 2009) or historic soil samples (EnSafe, Inc., 1996). The model predicts that this maximum soil concentration would not impact groundwater directly below the area of residual dinoseb concentrations in soil at Site 3 if biodegradation is occurring at the Site-specific calculated rate (0.0011/day). Impacts to groundwater also would not result, even without biodegradation, at the Facility boundary under either groundwater flow direction and gradient modeled. The model predicts that the current concentrations of dinoseb (average of 52.2 mg/kg) will not impact alluvial aquifer groundwater down-gradient of Site 3.

The model was also run to evaluate soil concentrations needed to prevent groundwater exceedances of the MCL (0.007 mg/L) in the alluvial aquifer directly below the center of residual dinoseb concentrations at Site 3 if no biodegradation was occurring. The model predicts that the soil concentration in the 4 to 8 ft bgs zone would need to be approximately 5.4 mg/kg or less under groundwater conditions measured in July 2008, or less than 1 mg/kg under conditions measured in September 2008. However, the observed decrease in soil dinoseb concentrations, as well as scientific references, provide evidence that biodegradation is occurring and expected to continue. Model results are summarized in Table 3-3.

3.7.5 Summary of Fate and Transport

Comparison of historic and current concentrations of dinoseb in subsurface soil at Site 3 indicate that natural attenuation mechanisms have reduced the concentration of dinoseb by over 99 percent since 1995. Modeling indicates that these mechanisms will prevent contamination of the alluvial aquifer groundwater underlying Site 3. Even without biodegradation, the model predicts that groundwater contamination will not reach to, or extend beyond, the Cedar Chemical Facility boundary.

Groundwater sampling results from 1993 through 2008 for monitoring wells 1MW-1, 1MW-7, EMW-6, EMW-6A, EMW-6B, and EMW-6C, located down-gradient of Site 3, are included as Table 3-4. Dinoseb results for these wells are mostly non-detect, with a few low, estimated (J-flagged) values reported. With the exception of one estimated (J-flagged) value from perched zone well EMW-6C collected in January 2008, all reported concentrations have been below the MCL for dinoseb [7 micrograms per liter (ug/L)]. These sample results support the results from the SESOIL and AT123D modeling and indicate that residual dinoseb concentrations in soil at Site 3 do not pose a risk to groundwater in the alluvial aquifer.

3.8 SUMMARY OF RISK ASSESSMENT AND REMEDIAL GOAL OPTIONS

Dinoseb was selected as a COC for subsurface soil for Site 3 in the 2001 Risk Assessment (EnSafe, Inc., 2001) based on a detection of 13,000 mg/kg in sample 3SB-6 (4-8 ft bgs). Of the five detections in subsurface soil during the 1996 FI, this detection was the only one that exceeded the USEPA Region 6 MSL, which was 680 mg/kg in 2001. Soil samples collected in the vicinity of sample 3SB-6 during the 2009 SI (AECOM, May 2009) were all below the current USEPA Region 6 MSL (620 mg/kg) (NOTE: the USEPA Region 6 MSL was updated in September 2008).

As part of this FS, an evaluation of remedial goal options (RGOs) for exposure pathways that are based on Site-specific conditions (which were not reviewed for dinoseb in the 2001 Risk Assessment and that cannot be addressed through the use of the USEPA Region 6 MSLs) has been conducted and is included in Appendix C. RGOs were developed for dinoseb, which was identified as contributing to unacceptable risk levels in subsurface in the Risk Assessment (EnSafe, Inc., 2001). Dinoseb was the only COC identified for subsurface soil at Site 3. The Risk Assessment did not identify dinoseb as a COC for perched or alluvial groundwater and, consequently, did not calculate an RGO for groundwater exposures. The evaluation of RGOs included in Appendix C evaluates Site-specific pathways that would be protective of the most likely exposure pathways to humans to dinoseb in soil at Site 3. These pathways include:

- Exposure to dinoseb in soil by an on-Site construction worker during digging or excavation,
- Migration of dinoseb in soil to perched zone groundwater where it could be contacted by an on-Site construction worker during digging or excavation,
- Migration of dinoseb in soil to alluvial aquifer groundwater and exposure of an off-Site agricultural worker during crop irrigation, and
- Migration of dinoseb in soil to alluvial aquifer groundwater and exposure of an off-Site resident using groundwater as potable water.

On-Site residential exposure pathways were not evaluated because the Facility has been recognized by ADEQ as an industrial facility and as likely to remain industrial (ADEQ, 2005). On-Site risk-based RGOs for on-Site industrial exposures (not construction-related exposure) were not included because the screening values developed by USEPA Region 6 for an outdoor industrial worker (i.e., not a construction worker) are recognized as sufficiently protective of this exposure pathway.

The risk-based RGOs for Site 3 are summarized below.

Risk-Based RGOs for Dinoseb in Soil at Site 3

Land Use/Receptor	Dinoseb Concentration in Soil (mg/kg)	
	Direct Contact	Protection of Groundwater
Industrial (On-Site Construction Worker)[1]	739	11
Off-Site Agricultural Worker[2]	NA	294
Off-Site Resident[3]	NA	1.5

NOTES:

1. The direct contact RGO (on-Site construction worker receptor) is based on the potential exposure of the future construction worker to subsurface soil at Site 3. The protection of groundwater RGO (on-Site construction worker receptor) is based on potential exposure of the future construction worker to perched zone water during construction activities.
2. The protection of groundwater RGO (off-Site agricultural worker receptor) is based on potential exposure of an agricultural worker to alluvial aquifer groundwater from an off-Site agricultural well.

[3.] The protection of groundwater RGO (off-Site resident receptor) is based on potential exposure of a resident to alluvial aquifer groundwater from a potable water well**.**
NA = not applicable

These soil RGOs were calculated using a simplistic Site-specific dilution attenuation factor (DAF), which was calculated using the Soil Screening Guidance (USEPA, 2002). The DAF calculated using this method does not account for the distance from the Site 3 of the potential down-gradient alluvial aquifer receptors and, as such, the resulting RGOs are conservative values that overestimate the potential for exposure and related risk.

4.0 REMEDIAL ACTION OBJECTIVES

Site-specific remedial response objectives are based on the results of the Risk Assessment and on the evaluation of applicable or relevant and appropriate requirements (ARARs) and "to be considered" (TBC) information. A summary of the Risk Assessment was presented in Section 3.7. Subsurface soil was identified in the Risk Assessment as the media of concern for dinoseb at Site 3. This section evaluates ARARs, TBC information, and RGOs for soil to develop overall RAOs. Groundwater, surface water, and sediment are not addressed since dinoseb was not identified as a COC for these media at Site 3 in the Risk Assessment (EnSafe Inc, 2001) or the Risk Evaluation (AEDQ, 2005). Based on this information, dinoseb does not pose a risk to potential receptors exposed to surface water and sediment from Site 3. Potential risk to groundwater resulting from the soil to groundwater pathway will be evaluated and potential groundwater receptors will be considered during the development of RAOs for dinoseb in subsurface soil at Site 3. ARARs are discussed in the following sections.

4.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA of 1980, as amended by the SARA of 1986, requires that remedial actions comply with requirements or standards set forth under federal and state environmental laws. Types of ARARs include action-specific, location-specific, and chemical-specific.

Remedies must consider "any promulgated standard, requirements, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation" if the former is applicable or relevant and appropriate to the Site and associated remedial activities (CERCLA 121(d)(2)(A). SARA requires that the remedial action for a Site meet all ARARs unless one of the following conditions is satisfied:

- The remedial action is an interim measure where the final remedy will attain the ARAR upon completion;
- Compliance will result in greater risk to human health and the environment than other options;
- Compliance is technically impracticable;
- An alternative remedial action will attain the equivalent of the ARAR; and
- For State requirements, the State has not consistently applied the requirement in similar circumstances.

In addition to ARARs, many federal and state environmental and public health programs also develop criteria, guidance, and proposed standards that are not legally binding, but that may provide useful information or recommended procedures (USEPA, October 1988). These TBCs are not potential ARARs but are reviewed along with ARARs and considered when setting remediation objectives (e.g., cleanup goals).

4.1.1 Definition of ARARs

Potential ARARs may be classified as either applicable or relevant and appropriate. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site, address problems or situations sufficiently similar to those encountered at the Site so that their use is well suited to the particular Site.

The determination that a requirement is relevant and appropriate is a two-step process: 1) determination if a requirement is relevant and, if relevant, 2) determination if a requirement is appropriate. In general, this involves a comparison of a number of Site-specific factors, including the characteristics of the remedial action, the hazardous substances present at the Site, or the physical circumstances of the Site, with those addressed in the statutory or regulatory requirement. In some cases, a requirement may be relevant but not appropriate based on Site-specific circumstances; such a requirement would not be an ARAR for the Site. In addition, there is more discretion in the determination of relevant and appropriate; it is possible for only part of a requirement TBC relevant and appropriate in a given case. When the analysis results in a determination that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable.

4.1.2 TBC Information

TBC requirements are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. However, as described below, TBCs may be considered along with ARARs as part of the risk assessment and may be used in determining the necessary level of cleanup for protection of health or the environment.

4.1.3 Types of ARARs

Three types of ARARs were developed to further clarify how to identify and comply with environmental requirements. These types are described in the following subsections.

4.1.3.1 Action-Specific ARARs

Action-specific requirements set controls or restrictions on the design, performance, and other aspects of implementation of specific remedial activities. Examples include RCRA regulations for off-Site disposal of hazardous residuals and the Clean Water Act standards for discharge of treated groundwater. Because action-specific ARARs apply to discrete remedial activities, their evaluation is discussed in Section 6.0 in the detailed analysis performed on each retained alternative. A retained alternative must conform to all ARARs unless one of the five statutory waivers listed in Section 4.1 is invoked.

4.1.3.2 Location-Specific ARARs

Location-specific ARARs must consider Federal, State, and local requirements that reflect the physiographical and environmental characteristics of the Site or the immediate area. Remedial actions may be restricted or precluded depending on the location or characteristics of the Site and the resulting requirements. A list of potential location-specific ARARs evaluated for the Site is provided in Table 4-1.

4.1.3.3 Chemical-Specific ARARs

Chemical-specific ARARs are concentration limits in the environment promulgated by government agencies. The NCP requires the development of health-based Site-specific levels for chemicals or media where such limits do not exist and there is a concern with their potential health or environmental impacts, where possible. Potential chemical-specific ARARs are discussed by media below.

4.2 REMEDIAL ACTION OBJECTIVES FOR SOIL

Following is a discussion of the chemical-specific ARARs, TBC information, RGOs, and conclusions concerning soil remediation for dinoseb at Site 3.

4.2.1 Chemical-Specific ARARs for Soils

Dinoseb has been identified as the only COC associated with exposure to subsurface soils by on-Site workers (security personnel), future construction workers and trespassers.

Federal chemical-specific ARARs for dinoseb in soil include:

- The USEPA Region 6 MSL of 620 mg/kg in industrial soil (USEPA Region 6, September 2008),
- The USEPA Region 6 Risk-Based SSL for protection of groundwater of 2.70E-1 mg/kg (USEPA Region 6, September 2008); and
- The USEPA Region 6 MCL-based SSL for protection of groundwater of 5.10E-02 mg/kg (USEPA Region 6, September 2008).

There are no other state or local chemical-specific ARARs for dinoseb in sub-surface soil at an industrial facility.

4.2.2 TBC Information

TBC information for dinoseb in subsurface soils at Site 3 includes the following:

- USEPA Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part A) Interim Final (December 1989);
- USEPA Soil Screening Guidance: User's Guide (July 1996);
- USEPA Region 4 Supplemental Guidance to RAGS: Region 4 Bulletins – Human Health Risk Assessment (Interim) (2000);
- USEPA Region 6 Human Health Medium-Specific Screening Levels (October 2000, September 2008);
- USEPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (December 2002);
- USEPA Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final (2004);
- USEPA 2006 Edition of the Drinking Water Standards and Health Advisories (August 2006);
- USEPA Region 6 Regional Screening Levels for Chemical Contaminants at Superfund Sites (2009); and
- USEPA Integrated Risk Information System (2009).

These resources were utilized in determining the RGOs.

4.2.3 Risk-Based RGOs for Soil

Dinoseb was identified as a final COC associated with exposure to subsurface soils at Site 3 by on-Site workers (security personnel) and trespassers (EnSafe, Inc., 2001; ADEQ 2005). Recent dinoseb soil sampling results (AECOM, May 2009) were significantly below the USEPA Region 6 MSL of 620 mg/kg, but exceeded the USEPA Region 6 MCL-based SSL of 5.10E-02 mg/kg.

In order to address the potential risk of soils further impacting groundwater, soil levels were calculated for dinoseb and selected as the final RGOs for dinoseb in subsurface soils at Site 3. The soil levels were calculated using a standard linear equilibrium soil/water partition equation to estimate contaminant release in soil leachate and a simple water-balance equation to calculate a dilution factor to account for dilution of soil leachate in an aquifer. The final RGOs for dinoseb in soils for Site 3 are 11 mg/kg for protection of the on-Site construction worker, 294 mg/kg for protection of the off-Site agricultural worker, and 1.5 mg/kg for protection of the off-Site resident.

4.2.4 Summary of Remediation Goals for Soils

Dinoseb in subsurface soils was identified in the Risk Evaluation (ADEQ, 2005) as a constituent in subsurface soil at Site 3 that could potentially further impact groundwater over time. However, SESOIL/AT123D modeling results (Section 3.7.4) and results from groundwater samples collected between 1993 and 2008 from monitoring wells down-gradient of Site 3 (Table 3-4) indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose on on-going risk to alluvial aquifer groundwater.

The soil to groundwater RGO for dinoseb was calculated to be 1.5 mg/kg (Section 3.8; based on potential exposure of an off-Site resident to alluvial aquifer water from a potable well). Although model simulations and groundwater sampling results indicate residual dinoseb concentrations in soil at Site 3 do not pose a risk to down-gradient receptors of alluvial aquifer groundwater, this value (1.5 mg/kg) will be adopted as the Site-specific cleanup level in this FS.

Based on the cleanup level, the residual concentrations of dinoseb in subsurface soil measured in March 2009 (AECOM, May 2009), the formula presented in equation 3-1 of Section 3.7.1, and the Site-specific calculated degradation rate (0.0011/day), it is estimated that natural attenuation mechanisms will reduce residual dinoseb concentrations to below the cleanup level in approximately ten (10) years.

4.3 AREA AND VOLUME ESTIMATION OF SOIL REQUIRING REMEDIATION

The area at Site 3with soils exceeding the Site-specific clean-up level (1.5 mg/kg) was estimated based on:

1. Soil samples collected during the Wormald SI (AECOM, May 2009), and
2. The location of non-detect results for dinoseb at Site 3 from the FI (EnSafe, Inc., 1996).

Subsurface soil sample concentrations were contoured using commercially available software (Surfer 9; Golden Software, Inc., 2009) to estimate the area exceeding the cleanup level. The estimated soil area requiring remedial action is approximately 0.26 acres or approximately 11,306 square ft (ft^2) (Figure 4-1). Using an approximate depth of impacted soil of 4 – 8 ft bgs, the estimated volume of soil is 45,224 cubic ft (ft^3) or 1,675 cubic yards (yd^3).

4.4 GENERAL RESPONSE ACTIONS

GRAs that aid in identifying remedial technologies to remediate soils based on the identified COCs, ARARs, and the proposed remediation goals are identified in this section. The focused GRAs for dinoseb in subsurface soil at Site 3 are:

1. No action;
2. Institutional controls;
3. Institutional controls and down-gradient groundwater monitoring, and
4. Engineered barrier with institutional controls and down-gradient groundwater monitoring.

These GRAs will be screened in Section 5.0 to determine if they are appropriate to reach remedial goals for dinoseb in subsurface soil at Site 3. The alternatives that are deemed appropriate after the screening process will be evaluated in detail in Section 6.0.

5.0 IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

The purpose of Section 5.0 is to identify and screen remediation technologies that may be appropriate for achieving remediation goals established for dinoseb in subsurface soil at Site 3. Selected technologies will be screened based on Site-specific effectiveness, technical implementability, and relative life-cycle cost. Those technologies that pass screening will be used to develop remediation alternatives which are subjected to detailed analysis and comparison in Section 5.0. Those technologies that are not effective, have implementation concerns, and/or are not economically feasible in comparison to other technologies are rejected in this section from further evaluation. Table 5-1 summarizes the identification and screening of remediation technologies potentially applicable to dinoseb in subsurface soil at Site 3.

5.1 SCREENING CRITERIA

Per the NCP, the three basic criteria for screening potentially applicable remediation technologies include effectiveness, implementability, and cost. Brief descriptions of these criteria are presented in the following subsections.

5.1.1 Effectiveness

The general effectiveness of each remediation technology is evaluated. A technology must be effective in reducing contaminant concentrations to established Site-specific remediation goals while minimizing or eliminating any short-term or long-term risk to human health or the environment during implementation. The technology must also avoid any adverse impacts to pubic health, pubic welfare, and the environment. Technologies that are ineffective at achieving Site remediation goals are eliminated from further consideration.

5.1.2 Implementability

The implementability of each remediation technology is evaluated. The implementability criterion addresses the technical and administrative feasibility of implementing a technology in a timely and cost effective manner. Site accessibility, usable area, potential future property use, and availability of services and materials as they relate to a technology are determined. In addition, preliminary consideration is given to regulatory constraints such as permitting that may affect certain remediation technologies. Technologies that are not technically or administratively implementable are removed from further consideration.

5.1.3 Cost

The relative life-cycle cost of each remediation technology is determined. Life-cycle costs include capital costs and operation and maintenance (O&M) costs and are based on a 10-year life cycle (see Section 4.2). Costs estimates presented in Section 5.0 are qualitative (low, moderate, high) and as a result are not as accurate as those costs presented in the detailed analysis and evaluation discussion in Section 6.0. Any technology which delivers similar levels of applicability, effectiveness, and implementability as other technologies, but has a significantly greater cost is eliminated. Technologies that are equivalent in cost but are clearly less effective than other retained technologies are also rejected. Otherwise, cost is not used as a criterion to screen remediation technologies at this stage in the FS.

5.2 IDENTIFICATION OF POTENTIALLY APPLICABLE REMEDIATION TECHNOLOGIES

Per the NCP, the No Action alternative is retained throughout the screening process in Section 5.0 and detailed evaluation in Section 6.0 to provide a comparative baseline against which other selected technologies can be compared.

Only subsurface soils are addressed in this FS. GRAs for Site soils were identified in Section 4.4. From these GRAs, soil remediation technologies are identified and screened below.

The following remediation alternatives were identified for consideration to achieve remediation goals for dinoseb in subsurface soil at Site 3:

- Alternative 1 - no action;
- Alternative 2 - institutional controls;
- Alternative 3 - institutional controls with down-gradient groundwater monitoring, and
- Alternative 4 - engineered barrier with institutional controls and down-gradient groundwater monitoring.

5.3 SCREENING OF SOIL REMEDIATION TECHNOLOGIES

In the following subsections, selected remediation technologies were screened for inclusion into remediation alternatives based on Site-specific effectiveness, implementability, and relative life-cycle cost in achieving the Site-specific RGO.

5.3.1 No Action

The No Action alternative is a stand-alone remediation response for subsurface soils at Site 3 that would not provide any engineered treatment of dinoseb. This technology relies solely on natural attenuation mechanisms to reduce dinoseb concentrations; however, there are no sampling events to quantify dinoseb reduction or to monitor dinoseb migration. Under the No Acton alternative, dinoseb-impacted soil is left in place without implementing any containment, removal, treatment, or other mitigating actions.

5.3.1.1 Effectiveness

For the No Action alternative, reductions in Site 3 soil dinoseb concentrations would not be expected other than those resulting from natural non-destructive attenuation processes (e.g., leaching, sorption, volatilization, etc.). The No Action alternative does not include soil monitoring, nor does it provide institutional controls to reduce the risk of potential exposure to dinoseb. There are no adverse impacts associated with the No Action alternative.

5.3.1.2 Implementability

The No Action alternative would not involve any design, equipment, construction activities, or permitting; therefore, it is readily implementable.

5.3.1.3 Cost

Costs associated with the No Action alternative may include costs associated with a periodic remedy review. This remedy review could include a Site visit and follow-up written summary every five (5) years for a period of ten (10) years. The relative life-cycle cost for the No Action alternative would be low.

5.3.1.4 Recommendation

As required by the NCP, the No Action alternative will be retained to provide a baseline for comparison of remediation alternatives developed in Section 6.0.

5.3.2 Institutional Controls

Deed restrictions are a type of institutional control, which are non-engineered, legally binding, administrative controls designed to protect human health and the environment. Deed restrictions limit human exposure by restricting activity, use, and access to properties with residual contamination. In this case, a deed restriction could be placed on the on-Site soils to not only protect future owner/operators of the property from exposure, but also to provide a measure of protection to the current owner of the property against future litigation.

The ADEQ currently maintains the Facility property and provides security for the Site. Security fencing has been installed around the former production area to keep trespassers out of the property. The Institutional Controls alternative includes the maintenance of the current fencing to provide security against trespassers.

The Risk Assessment (ADEQ, 2005) identified dinoseb as a COC in subsurface soil at Site 3 for exposure to on-Site workers and potential infiltration into groundwater. The Facility is fenced; the fence is currently maintained by the State. To provide additional protection to human receptors, a deed restriction for this area would be appropriate. The deed restriction may include requirements to maintain the existing Facility fencing, restrict property use to industrial only, restrict disturbance of soils, and/or require the use of appropriate personal protection equipment (PPE) if soils are disturbed.

5.3.2.1 Effectiveness

Soil deed restrictions would effectively protect human health by limiting exposure to dinoseb in subsurface soils above the RGOs. Deed restrictions can be achieved by notifying the Facility owners and future landowners of the potential presence of impacted soils and restricting the use of Site 3 in property deeds. Deed restrictions for this Site could include restrictions on the disturbance and use of soils and any other unauthorized encounter with subsurface soils that may potentially lead to constituent exposure. Maintenance of existing security fencing may be required to provide additional protection to human receptors by limiting access to Site 3. Under this option, reductions in soil constituent concentrations or a reduction in the potential for dinoseb infiltration into groundwater from soil would not be expected except through previously described natural attenuation processes. Groundwater monitoring would not be performed.

5.3.2.2 Implementability

There are no technical implementation issues to obtaining a deed restriction for on-Site soils.

5.3.2.3 Cost

The capital costs associated with obtaining a deed restriction for subsurface soil at Site 3 are low when compared to other more intensive soil remediation options. Annual costs associated with this option would be limited to annual inspections of the existing security fencing and maintenance of the fence line.

5.3.2.4 Recommendation

Institutional controls, including a deed restriction for on-Site soils, are retained for inclusion into comprehensive remediation alternatives developed in Section 6.0.

5.3.3 <u>Institutional Controls and Down-Gradient Groundwater Monitoring</u>

Institutional controls are discussed in Section 5.3.2 above. For this alternative, down-gradient groundwater monitoring for a period of ten (10) years would be implemented in addition to the institutional controls in order confirm dinoseb is not migrating from subsurface soils at Site 3 into groundwater down-gradient of the Site.

Groundwater monitoring will not require excavation, construction, disposal, and consequential disturbance to the surrounding environment. Groundwater dinoseb concentrations and distribution may be monitored annually or on an agreed-upon regular basis in existing down-gradient monitoring wells 1MW-1, 1MW-7, and EMW-6, EMW-6A, EMW-6B, and EMW-6C, which are illustrated on Figure 2-2 for a period of up to ten (10) years. Approximate flow directions in the alluvial aquifer are illustrated on Figures 3-3 and 3-4 for July 2008 and September 2008, respectively. The first monitoring event may serve as the baseline upon which to compare future monitoring results.

5.3.3.1 Effectiveness

Down-gradient groundwater monitoring could be effective in monitoring the concentration of dinoseb in groundwater and confirming that dinoseb is not migrating from subsurface soils into groundwater at Site 3.

5.3.3.2 Implementability

Groundwater monitoring could be implemented in a relatively short time period. Conventional, readily available equipment and standard laboratory analytical methods are used to monitor existing monitoring wells. Depending upon ongoing groundwater sampling results, additional monitoring wells may be required. The on-Site topography is favorable for the installation of any additional monitoring wells. Permits would be required for any new wells.

5.3.3.3 Cost

The capital costs associated with groundwater monitoring are lower when compared to other more aggressive soil technologies, due to the lack of design, construction, and implementation costs. Capital costs include any additional monitoring wells that may be required to supplement the existing monitoring well network. O&M costs are associated with periodic sampling and laboratory analysis and can be significant should monitoring be conducted for an extensive time period. Overall, the costs associated with groundwater monitoring are moderate.

5.3.3.4 Recommendation

Alternative 3 - institutional controls with down-gradient groundwater monitoring - is retained for further evaluation in Section 6.0.

5.3.4 Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring

The Risk Assessment (ADEQ, 2005) identified dinoseb as a COC in subsurface soil at Site 3 for exposure to on-Site workers and potential infiltration into groundwater. To ensure against continuing infiltration to groundwater, the area where subsurface soils exceed the RGO for dinoseb at Site 3 may be capped with a low-permeability cap (such as a compacted clay layer and vegetation). For this alternative the cap is combined with a deed restriction for this area to further reduce exposure to on-Site workers and down-gradient monitoring to confirm that dinoseb is not migrating from subsurface soil into alluvial aquifer groundwater at Site 3.

Institutional controls and groundwater monitoring were discussed in Sections 5.3.2 and 5.3.3 above, respectively.

5.3.4.1 Effectiveness

An low-permeablity cap could reduce the infiltration rate and, therefore, reduce the potential for residual dinoseb concentrations to leach into groundwater. The engineered barrier could mitigate the potential risk of residual dinoseb concentrations in soil impacting on-Site groundwater at Site 3 and off-Site groundwater in the alluvial aquifer. However, recent soil sample results (AECOM, May 2009) indicate that natural processes are working to effectively reduce residual concentrations of dinoseb in subsurface soil. Furthermore, Site-specific modeling and results from groundwater samples collected between 1993 and 2008 indicate that residual dinoseb concentrations do not pose a current or future risk to potential off-Site receptors of alluvial aquifer groundwater.

5.3.4.2 Implementability

The engineered barrier could be implemented in a relatively short time-frame. Conventional construction equipment and available fill material could be used to construct the low-permeability cap. The topography and layout of Site 3 is favorable for access with construction equipment.

5.3.4.3 Cost

Capitol costs associated with an engineered barrier are high compared to other alternatives. Capitol costs include heavy equipment rental and labor, fuel costs, and cost of cap material, fill, and vegetative cover material. Material costs could vary appreciably depending on the type and location of materials available at the time of implementation. O&M costs are associated with cover maintenance (e.g., mowing, reseeding, Site inspection) as well as groundwater sampling and laboratory costs described in Section 5.3.3. Overall, costs associated with an engineered barrier with institutional controls and down-gradient groundwater monitoring are moderate to high.

5.3.4.4 Recommendation

Alternative 4 – engineered barrier with institutional controls and down-gradient groundwater monitoring - is retained for further evaluation in Section 6.0.

5.4 SUMMARY OF RETAINED TECHNOLOGIES

The following remediation alternatives for dinoseb in subsurface soil at Site 3 were retained for alternative development in Section 6.0 of the FS:

1. Alternative 1 - no action;
2. Alternative 2 - institutional controls;
3. Alternative 3 - institutional controls and down-gradient groundwater monitoring, and
4. Alternative 4 - engineered barrier with institutional controls and down-gradient groundwater monitoring.

6.0 DEVELOPMENT AND DETAILED EVALUATION OF REMEDIATION ALTERNATIVES

The alternatives that were retained from the initial screening process in Section 5.0 are assembled into comprehensive remediation alternatives and each is subjected to a detailed evaluation in this section. Detailed analysis of the comprehensive alternatives is conducted in two distinct phases. Initially, alternatives are individually assessed against the nine evaluation criteria. Results of the individual analyses are then used to compare the alternatives against one another to identify advantages, disadvantages, and tradeoffs between the alternatives.

6.1 REMEDIATION ALTERNATIVE ASSEMBLY

This section presents the technologies described in Section 5.0 as functional remediation alternatives. These alternatives were selected based on successfully passing screening and are believed to be the most appropriate technologies based on Site-specific conditions. The No Action alternative is used as a baseline for comparison among the alternatives to be evaluated. Recommended remediation alternatives to address dinoseb in subsurface soil at Site 3 include:

- Alternative 1 – No Action;
- Alternative 2 –Institutional Controls;
- Alternative 3 –Institutional Controls and Down-Gradient Groundwater Monitoring; and
- Alternative 4 – Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring.

6.2 EVALUATION CRITERIA

A detailed analysis of the aforementioned remediation alternatives is performed against the nine evaluation criteria to form the basis for selecting a final Site remedy. The intent of this analysis is to present sufficient relevant information to allow decision-makers to select an appropriate remedy. evaluation against the nine criteria forms the basis for determining the ability of a remedial action alternative to satisfy remedy selection requirements. A description of the nine criteria as outlined in Title 40 of the Code of Federal Regulations (CFR) Part 300.430(e)(9)(iii) is presented in the following subsections.

6.2.1 Protective of Human Health and the Environment

Remediation alternatives must be protective of human health and the environment. Each alternative is assessed to determine whether it can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by constituents present at the Site by eliminating, reducing, or controlling exposure to the established Site-specific remediation goals. The overall assessment of protection utilizes the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

6.2.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

The alternatives are assessed to determine whether they meet ARARs under federal and state environmental laws as presented in Section 4.0 of this FS. Compliance with other criteria, advisories, and guidance is also evaluated.

6.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion evaluates the anticipated ability of the alternatives to maintain reliable protection of human health and the environment over time, once the remediation goals are met. Alternatives are assessed for the long-term effectiveness and permanence they afford with respect to the magnitude of residual risk and the adequacy and reliability of controls used to manage residual dinoseb (untreated dinoseb and treatment residuals) over the long-term.

6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion addresses the anticipated performance of the treatment technologies that each alternative employs. This evaluation relates to the statutory preference for selecting an alternative that utilizes treatment technologies to eliminate residuals or substantially reduce the inherent potential for residual dinoseb at Site 3 to cause future environmental releases or other risks to human and the environment. Estimates of the degree to which the remediation alternative will reduce dinoseb toxicity, mobility, and/or mobility are beneficial when analyzing this factor.

6.2.5 Short-Term Effectiveness

The short-term impacts of the implementation period for each of the alternatives are assessed, considering the following factors, as appropriate:

- Short-term risks that might be posed to the community during implementation of an alternative;
- Potential impacts to industrial or remediation workers during remedial action and the effectiveness and reliability of protective measures;
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
- Time required to achieve Site-specific media cleanup goals.

6.2.6 Implementability

The ease or difficulty of implementing the remediation alternatives is assessed by considering the following factors, as appropriate:

- Technical feasibility, including the reliability of the remedy, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy;
- Administrative feasibility, including activities required to coordinate with other offices and agencies and the ability and time needed to obtain any necessary approvals and permits for both on-Site and off-Site activities; and
- Availability of necessary goods and services and materials.

6.2.7 Cost

Cost estimates for remediation alternatives are presented for comparison purposes only, are order-of-magnitude level, and have an estimated range of accuracy of -30% to +50%. The cost estimates include both capital and O&M costs. Present worth costs are determined over the time period of operation at a 3% discount rate, based on an interest rate of 7% and an inflation rate of 4 %. Detailed costs estimates for each of the three remediation alternatives are provided in Appendix D.

6.2.8 State Acceptance

Based on the Risk Evaluation included as Attachment D of the *Cedar Chemical Company: Request for Proposal Package* (ADEQ, August 2005), the State has identified dinoseb in subsurface soil at Site 3 as an on-going risk to potential future construction workers and as a potential risk to groundwater through leaching from soil. Scenarios that address the risks posed by these pathways are anticipated to be accepted by the State.

Concentrations of dinoseb detected in subsurface soil at Site 3 during the March 2009 Wormald Site Investigation (AECOM, May 2009) do not exceed the EPA Region 6 MSL for industrial soil or the Site specific direct contact RGO (739 mg/kg) for potential exposure of the on-Site construction worker to subsurface soil (Section 3.8). Concentrations do exceed the direct contact RGO for potential exposure of an on-Site construction worker to perched zone water (11 mg/kg, Section 3.8), so the construction worker exposure scenario will need to be addressed by the selected remedy. The concentrations also exceed the Site-specific risk-based RGO for protection off-Site residents exposed to alluvial aquifer groundwater (1.5 mg/kg, Section 3.8). However, the DAF equation used to calculated RGOs for off-Site groundwater exposure scenarios is simplistic and does not account for the distance between Site 3 and the off-Site point of exposure (i.e., it does not take into account the distance to the Facility property boundary). SESOIL/AT123D modeling and groundwater sampling results (Table 3-4) indicate residual concentrations of dinoseb in subsurface soil at Site 3 do not pose an on-going risk the alluvial aquifer groundwater. Furthermore, the reduction in subsurface soil concentrations of dinoseb at Site 3 between 1995 and 2009 indicates that natural attenuation mechanisms are working to reduce dinoseb concentrations at Site 3.

6.2.9 Community Acceptance

In general, alternatives which move toward the redevelopment of the former Cedar Chemical Facility Property are anticipated to be accepted by the community following any applicable public comment period which may be required by the state. This assessment evaluates the issues and concerns the public may have regarding each of the alternatives.

6.3 DETAILED CRITERIA EVALUATION FOR REMEDIATION ALTERNATIVES

The following subsections present the detailed criteria evaluation for Alternatives 1 through 4.

6.3.1 Alternative 1 – No Action

The No Action alternative provides a baseline for comparing all other remediation alternatives. Human health and environmental risks for the Site would initially remain the same as those identified in the Risk Assessment and summarized in Section 2.0 and 3.0 of this FS. However, natural attenuation mechanisms will reduce risk over time. The only receptor identified in the Risk Assessment (EnSafe, Inc., 2001) as potentially at risk is the hypothetical future industrial worker exposed to on-Site subsurface soil, but potential risk to groundwater through leaching of soil contaminants is also a concern at the Site (ADEQ, 2005).

6.3.1.1 Protective of Human Health and the Environment

Alternative 1 provides reduction in future risk to the identified hypothetical Site receptor through natural attenuation mechanisms; however, it does not protect current or future on-Site construction workers from exposure to soil or perched zone groundwater during digging or construction activities. No monitoring is included with this alternative to verify the reduction in risk to human health and the environment over time.

6.3.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Alternative 1 would result in a reduction of dinoseb concentrations over time in soil and fate and transport modeling results discussed in Section 3.7.4 indicate the current soil concentrations do no pose a risk for off-Site alluvial aquifer groundwater exposure; however, no monitoring is included to verify this reduction. Furthermore, this remedy by itself does not address potential exposure of future construction workers during excavation activities. This remedy would not meet Site RGOs, including ARARs, within a reasonable time frame.

6.3.1.3 Long-Term Effectiveness and Permanence

This alternative in and of itself includes no controls for exposure and no long-term management measures. All potential future risks would remain, although natural attenuation mechanisms would reduce risk over time. Five-year remedy reviews may be required and may include a Site inspection with photo documentation, a review of applicable regulations, a meeting with ADEQ to discuss the Site status, and preparation of a summary report.

6.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not provide any reduction in toxicity, mobility, or volume of Site-related constituents through treatment; however, natural attenuation would result in the reduction of dinoseb concentrations in all media over time.

6.3.1.5 Short-Term Effectiveness

There would be no additional risks posed to the community, workers, or the environment as a result of this alternative. Based on historical Site data and Site-specific degradation rate calculated in Section 3.7.1, the estimated time to achieve Site 3 soil cleanup goals would be approximately ten (10) years.

6.3.1.6 Implementability

There are no implementability concerns posed by this alternative since no action would be taken.

6.3.1.7 Cost

The 10-year present worth cost of Alternative 1 is estimated to be $7,008 and is based solely on the completion of 5-year reviews. Table 6-1 presents a summary of the costs associated with Alternative 1; the detailed cost estimate is presented in Appendix D.

6.3.2 <u>Alternative 2 –Institutional Controls</u>

The Institutional Controls alternative includes a property deed restriction to ensure that:

- The Property zoning remains industrial;
- The existing security fencing is maintained to prohibit trespassers and control incidental exposure; and
- Proper PPE is worn by construction workers during earth-moving activities to protect them from exposure to subsurface soil at Site 3 and Perched Zone groundwater.

6.3.2.1 Protective of Human Health and the Environment

Alternative 2 would limit exposure risk to future on-Site construction workers by ensuring the use of proper PPE and natural attenuation mechanisms will reduce future risk to the identified hypothetical Site receptor over time. No monitoring is included with this alternative to verify the reduction in risk to human health and the environment over time.

6.3.2.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Alternative 2 would immediately reduce the risk to on-Site workers upon incorporation of the deed restriction and would prohibit potential trespassers from accessing the Site. This alternative would result in a reduction of constituent concentrations over time in soil. Fate and transport modeling results discussed in Section 3.7.4 indicate the current dinoseb concentrations in subsurface do no pose a risk for off-Site groundwater exposure; however, no monitoring is included to verify this reduction. This remedy would address RGOs for on-Site exposure. Based on the Site-specific degradation rate calculated in Section 3.7.1, it will take approximately ten (10) years to meet RGOs for the protection of groundwater.

For this Alternative, a property deed restriction will be prepared and filed with the Phillips County Recorder in accordance with Arkansas Codes 14-15-402 (Instruments to be recorded) and 14-14-403 (Instruments affecting title to property).

6.3.2.3 Long-Term Effectiveness and Permanence

This alternative includes controls for exposure to trespassers and on-Site workers. Maintenance of the existing fence line and land use controls provides long-term risk-management measures. Historic Site data indicate natural attenuation mechanisms would reduce risk over time and fate and transport modeling indicates that residual dinoseb concentrations in subsurface soil at Site 3 do not pose a threat to off-Site groundwater. Annual inspections may be required to ensure that existing Site security fencing is maintained. Five-year remedy reviews may be required and may include a Site inspection with photo documentation, a review of applicable regulations, a meeting with ADEQ to discuss the Site status, and preparation of a summary report.

6.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 does not provide any reduction in toxicity, mobility, or volume of dinoseb concentrations in subsurface soil at Site 3 through treatment; however, natural attenuation would result in the reduction of dinoseb in all media over time.

6.3.2.5 Short-Term Effectiveness

There would be no additional risks posed to the community, workers, or the environment as a result of this alternative. This alternative would control exposure to trespassers and on-Site workers immediately upon incorporation of the deed restriction. Based on historical Site data and Site-specific degradation rate calculated in Section 2.7.1, the estimated time to achieve cleanup goals for dinoseb in soil at Site 3 would be approximately ten (10) years.

6.3.2.6 Implementability

There are no technical implementation issues to obtaining a deed restriction for on-Site soils. The State currently manages the property and maintains security fencing. The long-term maintenance of security fencing would need to be addressed by prospective buyers of the Facility property

6.3.2.7 Cost

The 10-year present worth cost of Alternative 2 is estimated to be $28,866 and is based on

- Cost of filing the Deed Restriction with the Phillips County Recorder;
- Legal cost to prepare the Deed Restriction;
- Cost for annual Site inspection visits to ensure Site security;
- Cost for maintenance of Site security fencing; and
- The completion of 5-year reviews, including agency meeting and reporting.

Table 6-2 presents a summary of the costs associated with Alternative 2; the detailed cost estimate is presented in Appendix D.

6.3.3 Alternative 3 –Institutional Controls and Down-Gradient Groundwater Monitoring

The Institutional Controls and Down-Gradient Groundwater Monitoring alternative includes a property deed restriction as described for Alternative 2 in Sections 6.3.2. It also includes annual monitoring of groundwater monitoring wells 1MW-1, 1MW-7, EMW-6, EMW-6A, EMW-6B, and EMW-6C to verify that residual dinoseb concentrations in subsurface soils are not leaching into groundwater.

6.3.3.1 Protective of Human Health and the Environment

Alternative 3 would limit exposure risk to future on-Site construction workers by ensuring the use of proper PPE and natural attenuation mechanisms will reduce future risk to the identified hypothetical Site receptor over time. This scenario addresses the risk to on-Site workers, prohibits potential trespassers, and includes monitoring is to verify the reduction in risk to human health and the environment over time.

6.3.3.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Alternative 3 would immediately reduce the risk to on-Site workers upon incorporation of the Deed Restriction and would prohibit potential trespassers from accessing the Site. This alternative would result in a reduction of dinoseb in subsurface soil at Site 3 over time. Fate and transport modeling results discussed in Section 3.7.4 indicate the current dinoseb concentrations in subsurface soil do not pose a risk for off-Site groundwater exposure, and this alternative includes down-gradient groundwater monitoring to verify the modeling results. Although this remedy would address RGOs for on-Site exposure, it would take approximately ten (10) years to meet RGOs for the protection of groundwater based on historic Site data.

For this alternative, deed restrictions will be prepared and filed with the Phillips County Recorder in accordance with Arkansas Codes 14-15-402 (Instruments to be recorded) and 14-14-403 (Instruments affecting title to property).

6.3.3.3 Long-Term Effectiveness and Permanence

This alternative includes controls for exposure to trespassers and on-Site workers, and provides monitoring to ensure the protection of residents and agricultural workers using groundwater down-gradient of the Site. Maintenance of the existing fence line, land use controls and groundwater monitoring provide long-term risk-management measures. Historic Site data indicate natural attenuation mechanisms would reduce risk over time and fate and transport modeling indicates that residual dinoseb concentrations in subsurface soil at Site 3 do not pose a threat to off-Site groundwater. Annual inspections may be required to ensure that existing security fencing is maintained and may combined with groundwater sampling visits. Five-year remedy reviews may be required and may include a Site inspection with photo documentation, a review of applicable regulations, a meeting with ADEQ to discuss the Site status, and preparation of a summary report.

6.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 does not provide any reduction in toxicity, mobility, or volume of dinoseb in subsurface soil at Site 3 through treatment; however, natural attenuation would result in the reduction of dinoseb concentrations in all media over time and monitoring will provide a verification of the reduction.

6.3.3.5 Short-Term Effectiveness

There would be no additional risks posed to the community, workers, or the environment as a result of this alternative. This alternative would control exposure to trespassers and on-Site workers immediately upon incorporation of the Deed Restriction. Sampling of down-gradient monitoring wells will protect residents and agricultural workers by providing a method of monitoring potential exposure. Based on historical Site data and the Site-specific degradation rate calculated in Section 3.7.1, the estimated time to achieve Site cleanup goals would be approximately ten (10) years.

6.3.3.6 Implementability

There are no technical implementation issues to obtaining a deed restriction for on-Site soils or for conducting annual groundwater sampling events. The State currently manages the property and maintains security fencing. The long-term maintenance of security fencing would need to be addressed by prospective buyers of the Facility property. Permission to access the wells for groundwater sampling would need to be coordinated with the ADEQ or future property owners.

6.3.3.7 Cost

The 10-year present worth cost of Alternative 3 is estimated to be $73,298 and is based on

- Cost of filing the Deed Restriction with the Phillips County Recorder;
- Legal cost to prepare the Deed Restriction;
- Cost for annual Site inspection visits to ensure Site security;
- Cost for maintenance of Site security fencing;
- Cost for conducting annual groundwater sampling; and
- The completion of 5-year remedy reviews, including meeting the State and reporting.

Table 6-3 presents a summary of the costs associated with Alternative 3; the detailed cost estimate is presented in Appendix D.

6.3.4 Alternative 4 – Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring

The Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring alternative includes a low-permeability cover to reduce infiltration and, therefore, leaching potential at Site 3. From bottom to top, the cover may be comprised of:

- 12-inches of moderately compacted clay (hydraulic conductivity of 1X10E-09 cm/sec or less) or similar material to reduce infiltration;
- 6-inches of top soil to protect the clay and promote growth of vegetation; and
- Vegetative cover (e.g., grass).

A schematic of the Engineered Barrier is included as Figure 6-1. The Engineered Barrier would be emplaced over the estimated area for soil remediation illustrated on Figure 4-1 and is expected to cover approximately 0.26 acres.

Alternative 4 also includes institutional controls and down-gradient groundwater monitoring as described in Section 6.3.3.

6.3.4.1 Protective of Human Health and the Environment

Alternative 4 would reduce the potential risk to groundwater by reducing the infiltration rate across the ”capped area” in Site 3. The alternative limits exposure risk to future on-Site construction workers by ensuring the use of proper PPE. Natural attenuation mechanisms will reduce future risk to the identified hypothetical Site receptor over time. This scenario addresses the risk to on-Site workers and includes monitoring is to verify the reduction in risk to human health and the environment over time.

6.3.4.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Alternative 4 would immediately reduce the risk to on-Site workers upon incorporation of the deed restriction and would prohibit potential trespassers from accessing the Site. The Engineered Barrier could reduce the risk to groundwater by reducing the infiltration rate in the “capped area” of Site 3 and this alternative includes down-gradient groundwater monitoring to verify this reduction. Natural attenuation mechanisms would continue to reduce of dinoseb concentrations over time in soil, but the reduced infiltration rate may result in a longer residence time for dinoseb in soil.

Leachate modeling using the Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder, et. al., 1994) indicates the Engineered Barrier would be effective in reducing the infiltration rate at the Site to 0.32 cm/year (Appendix E). Based on the revised infiltration rates, a revised DAF and revised RGO for the soil to groundwater pathway were calculated and are presented in Appendix F. The revised risk-based RGO for the potential exposure of an off-Site resident to alluvial aquifer groundwater is 52.9 mg/kg. Based on historic Site data and equation 3.1 in Section 3.7.1, it would take approximately two (2) years to meet the revised RGOs for protection of groundwater. However, because this alternative does not reduce concentrations of dinoseb in subsurface soil, it is estimated natural attenuation mechanisms will take approximately ten (10) years to reduce residual soil concentrations to the Site-specific cleanup goal.

RGOs for on-Site exposure would be addressed by the Institutional Controls. For this alternative, deed restrictions would be prepared and filed with the Phillips County Recorder in accordance with Arkansas Codes 14-15-402 (Instruments to be recorded) and 14-14-403 (Instruments affecting title to property).

6.3.4.3 Long-Term Effectiveness and Permanence

This alternative includes controls for exposure to trespassers and on-Site workers, and provides monitoring to ensure the protection of residential and agricultural use of alluvial aquifer groundwater down-gradient of Site 3. Maintenance of the existing fence line, land use controls and groundwater monitoring provide long-term risk-management measures. HELP modeling (Appendix E) indicates the Engineered Barrier will effectively reduce the infiltration rate in the “capped area” at Site 3, thereby reducing the potential risk to off-Site receptors of alluvial aquifer groundwater. Annual inspections may be required to ensure that existing Site security fencing is maintained and may be combined with groundwater sampling Site visits. O&M of the engineered barrier would also be required to ensure its long-term effectiveness. Five-year remedy reviews may be required and may include a Site inspection with photo documentation, a review of applicable regulations, a meeting with ADEQ to discuss the Site status, and preparation of a summary report.

6.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4 could reduce the mobility of dinoseb in subsurface soil by reducing the infiltration rate through the impacted media. The alternative does not provide any reduction in toxicity or volume of residual dinoseb concentrations in subsurface soil at Site 3 through treatment; however, natural attenuation would result in the reduction of constituent concentrations in all media over time and monitoring will provide a verification of the reduction.

6.3.4.5 Short-Term Effectiveness

There would be no additional risks posed to the community, workers, or the environment as a result of this alternative. This alternative would control exposure to trespassers and on-Site workers immediately upon incorporation of the Deed Restriction. The engineered barrier could reduce the potential risk to groundwater and sampling of down-gradient monitoring wells could provide a method of monitoring potential exposure. Based on historical Site data and revised RGOs for this alternative, the time estimated to achieve the revised soil to groundwater RGO would be approximately two (2) years as long as the Engineered Barrier is maintained. However, as with the other scenarios, it is estimated natural attenuation mechanisms will take approximately ten (10) years to reduce residual soil concentrations to the Site-specific cleanup goal.

6.3.4.6 Implementability

There are no technical implementation issues to obtaining a deed restriction for on-Site soils or for conducting groundwater sampling events. The State currently manages the property and maintains security fencing. The long-term maintenance of security fencing would need to be addressed by prospective buyers of the Facility property. Permission to access the wells for groundwater sampling would need to be coordinated with the ADEQ or future property owners.

The topography and layout of Site 3 is favorable for access with construction equipment and the engineered barrier could be implemented in a relatively short time-frame. Conventional construction equipment and available fill material could be used to construct the impermeable cap. No technical implementation issues are expected; however, if the expected construction materials are not available at the time of implementation, additional design work would need to be performed and alternative materials would have to be selected.

6.3.4.7 Cost

The 10-year present worth cost of Alternative 4 is estimated to be $95,889 and is based on

- Cost of filing the Deed Restriction with the Phillips County Recorder;
- Legal cost to prepare the Deed Restriction;
- Material and labor costs to install the Engineered Barrier;
- Cost for annual Site inspection visits to ensure Site security;
- Cost for maintenance of Site security fencing;
- Cost for conducting annual groundwater sampling; and
- The completion of 5-year remedy reviews, including meeting with the State and reporting.

Table 6-4 presents a summary of the costs associated with Alternative 4; the detailed cost estimate is presented in Appendix D

6.4 COMPARATIVE ANALYSIS OF REMEDIATION ALTERNATIVES

A detailed comparative analysis of the four remediation alternatives evaluated for dinoseb in subsurface soil at Site 3 is presented in the following subsections. Comparisons are presented below for each criterion and are summarized in Table 6-5.

6.4.1 Protective of Human Health and the Environment

Alternative 1, the No Action scenario, does not provide any protection of human health or the environment. All scenarios rely on natural attenuation mechanisms to reduce residual dinoseb concentrations over time. Alternatives 2 through 4 prohibit potential trespassers from accessing the Site and protect on-Site workers through the use of Land Use Controls, Site Security, and minimum PPE requirements.

Fate and transport modeling discussed in Section 3.7.4 and the results of groundwater samples collected since 1993 indicate the current soil concentrations do not pose a risk for off-Site groundwater exposure. Therefore, the addition of down-gradient groundwater sampling and analysis to monitor potential migration of dinoseb along the soil to groundwater pathway does not offer any additional protection for off-Site receptors of alluvial aquifer groundwater. Furthermore, Alternative 3 is not recommended since it does not reduce the time to reach the Site-specific cleanup goal.

Alternative 4 includes an Engineered Barrier which may reduce the infiltration rate and limit the mobility of dinoseb along the soil to groundwater pathway; however, implementation of this remedy may result in a longer residence time for dinoseb in subsurface soil. Furthermore, since this scenario relies on natural attenuation mechanisms to reduce dinoseb concentrations in subsurface soil, the time to reach the Site-specific cleanup goal is the same as for other alternatives.

6.4.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

Although Alternative 1 would result in a reduction of constituent concentrations, it does not include any controls to ensure protection of on-Site workers over the time frame necessary to reach Site-specific RGOs. Alternatives 2 through 4 each address the on-Site exposure risks through the implementation of Institutional Controls.

Fate and transport modeling results discussed in Section 3.7.4 indicate the current soil concentrations do not pose a risk for off-Site groundwater exposure. Alternatives 3 and 4 include monitoring to further ensure there is no risk to off-Site residents and agricultural workers exposed to groundwater down-gradient of Site 3. However, fate and transport modeling and results from groundwater samples collected since 1993 indicate that the soil concentrations do not pose a risk for off-Site groundwater exposure.

Alternative 4 addresses the potential for leaching by reducing infiltration at Site 3. Because of the revised RGO associated with Alternative 4, a shorter time to reach the Site-specific risk-based RGO for the soil to groundwater pathway is expected with this alternative. However, the revised RGO would be effective only so long as the Engineered Barrier remains in place, so the time frame of implementation would be the same as for other remedies. Furthermore, reduced infiltration at Site 3 could result in a longer residence time for dinoseb in subsurface soil.

Alternative 2 is the recommended alternative to comply with ARARs and other criteria since it addresses the RGO for direct contact of the future construction worker, includes measures to prevent potential incident exposure to Site 3 soil, and is expected to achieve the Site-specific cleanup goal in the same time frame as other alternatives.

6.4.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide long-term effectiveness and permanence. No controls of human exposure to soil or groundwater would occur under Alternative 1. Alternatives 2 through 4 achieve long-term effectiveness and permanence through invocation of deed restrictions that would control human exposure to on-Site soil and groundwater.

6.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

All alternatives would reduce the volume in soil through natural attenuation. The institutional controls included in Alternatives 2 through 4 provide an immediate reduction in risk for on-Site exposure pathways. Alternative 4 could reduce the volume of leachate produced by limiting the infiltration rate over dinoseb impacted soils and, therefore, could reduce the potential risk to off-Site groundwater. However, because all scenarios rely on natural attenuation mechanisms to reduce residual dinoseb concentrations in subsurface soil, the time to reach the Site-specific cleanup goal is the same for all alternatives.

6.4.5 Short-Term Effectiveness

None of the alternatives pose any short-term risk to remedial workers or the community.

6.4.6 Implementability

All alternatives are easily implementable. Alternative 1 would be the most easily implementable followed by Alternative 2, then Alternative 3, and then Alternative 4. Alternatives 2 through 4 require deed restrictions to control on-Site exposure. Alternatives 3 and 4 will require prior notification to the State or future property owner to access the wells for annual monitoring. Alternative 4 will require the location of construction materials and procurement of subcontractors prior to implementation.

6.4.7 <u>Cost</u>

Alternative 1 is the least costly alternative followed by Alternative 2, then Alternative 3, and then Alternative 4. Alternative 1 includes 5-year remedy reviews at a present worth cost of $7,008 over a 10-year period. The present worth cost for Alternatives 2, 3, and 4 are $28,866, $73,298, and $95,889, respectively, over a 10-year period.

6.5 JUSTIFICATION AND RECOMMENDATION FOR THE PREFERRED REMEDY

Based on the detailed and comparative evaluations of remedial alternatives, the selected remedial alternative is Alternative 2 – Institutional Controls. Alternative 2 best meets the objective of reducing risk to on-Site workers, future on-Site construction workers, and trespassers through the use of natural attenuation mechanisms and Institutional Controls. Soil concentrations will be reduced over time by natural attenuation mechanisms. A summary of the Site-specific data considered during the evaluation and selection process is provided below.

- Site 3 is comprised of 3 storm water ditches and surrounding soils south of the main production area of the Facility. No process units existed at Site 3 and there were no documented manufacturing activities conducted in this area.
- During the FI (EnSafe, Inc., 1996), the reported dinoseb concentrations from five soil samples collected from Site 3 ranged from 0.63 mg/kg to 13,000 mg/kg. The concentration of dinoseb in one soil sample collected from the 4-8 ft depth interval of soil boring location 3SB-6 (13,000 mg/kg) exceeded the EPA Region 6 MSL for dinoseb in industrial soil. Dinoseb was subsequently identified as a COC for subsurface soil at Site 3 in the Risk Assessment (EnSafe, Inc., 2001).
- Sediment samples collected during the FI (EnSafe, Inc., 1996) were predominantly non-detect for dinoseb. Furthermore, dinoseb was not selected as a COC for sediment or groundwater at Site 3 (EnSafe, Inc., 2001; ADEQ, 2005) and does not pose a risk to human health and the environment for these media.
- Confirmation sampling was performed at historical sample location 3SB-6 to assess the current concentration of dinoseb in subsurface soil (AECOM, May 2009). Dinoseb concentrations ranged from 31.3 mg/kg to 80.4 mg/kg in the five soil samples collected; this concentration range is three orders of magnitude lower (99% reduction) than the historic concentration, 13,000 mg/kg, reported in sample 3SB-6 (4-8 ft bgs).
- All concentrations of dinoseb detected in subsurface soil during the 2009 Wormald SI (AECOM, May 2009) were less than:

- o The EPA Region 6 MSL for dinoseb in industrial soil (620 mg/kg);
- o The Site-Specific risk-based RGO calculated for potential future construction worker exposure to subsurface soil at Site 3 (739 mg/kg); and
- o The Site-specific risk-based RGO calculated for potential agricultural worker exposure to alluvial aquifer groundwater (294 mg/kg).

- The only RGOs exceeded were the Site-specific risk-based RGO for potential future construction worker exposure to perched zone water (11 mg/kg) and the Site-specific risk-based RGO for potential resident exposure to alluvial aquifer groundwater (1.5 mg/kg).
- Literature values for the half-life of dinoseb in soil range from _30 days to 123 days (see Section 3.7.1 of this FS). Based on Site-specific physical and chemical characteristics of subsurface soil at Site 3, a Site-specific half-life of approximately 630 days (degradation rate of 0.0011/day) was calculated. This Site-specific half-life is more conservative than literature values cited above.
- Site-specific physical and chemical properties were used to model the fate and transport of dinoseb in subsurface soil at Site 3 and evaluate the potential of residual dinoseb concentrations to leach into groundwater beneath the Site. Model simulations were performed with and without the inclusion of degradation to evaluate potential migration under the most conservative assumptions.
- The model was run with soil concentrations three orders of magnitude greater than the highest historic dinoseb concentration detected at Site 3 (13,000 mg/kg in historic soil sample 3SB-6). Using the Site-specific half-life for dinoseb in soil (630 days), model results predict that concentrations of dinoseb in alluvial aquifer groundwater will not exceed the MCL (7 ug/L) at the property boundary (the exposure point for residential and agricultural use). Model simulation without degradation using 2009 soil quality data also indicate that concentrations of dinoseb in alluvial aquifer groundwater will not exceed the MCL at the property boundary, indicating no risk from dinoseb to potential off-Site groundwater receptors.
- Concentrations of dinoseb in alluvial aquifer groundwater have not exceeded the MCL in monitoring wells down-gradient of Site 3 in any sample collected over a period of 15 years between 1993 and 2008 (Table 3-4).
- The present worth life-cycle costs associated with alternatives 3 and 4 are more than those associated with alternative 2. However, since all four alternatives rely on natural attenuation mechanisms to reduce soil concentrations over time, the expected time to reach the Site-specific clean-up goal is the same for all four alternatives; and there is little to be gained in additional protection of human health and the environment with the adoption of alternatives 3 or 4.

Based on the information presented above, the residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a current or future risk to off-Site receptors of alluvial aquifer groundwater. Therefore, the only remaining risk from residual dinoseb in subsurface soil at Site 3 is the risk of potential exposure of future construction workers to perched zone water. Alternative 2 – Institutional Controls – is an appropriate and cost-effective remedial alternative for residual dinoseb concentrations in subsurface soil at Site 3. Furthermore, Site-specific soil quality data indicate that residual dinoseb concentrations in subsurface soil at Site 3 will continue to be reduced naturally over a relatively short period of time through natural attenuation processes occurring at the Site. Alternative 2 is the preferred remedial alternative for dinoseb in subsurface soil at Site 3 to protect human health and the environment in accordance with the NCP of November 20, 1985 (50 FR 47973) and the amended NCP of March 5, 1990 (55 FR 8666).

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FIGURES

Source: TerraServer DRG
(West Helena, Arkansas, United States)

AECOM

Figure 2-1
Site Location Map
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

June 2009 104336

AECOM

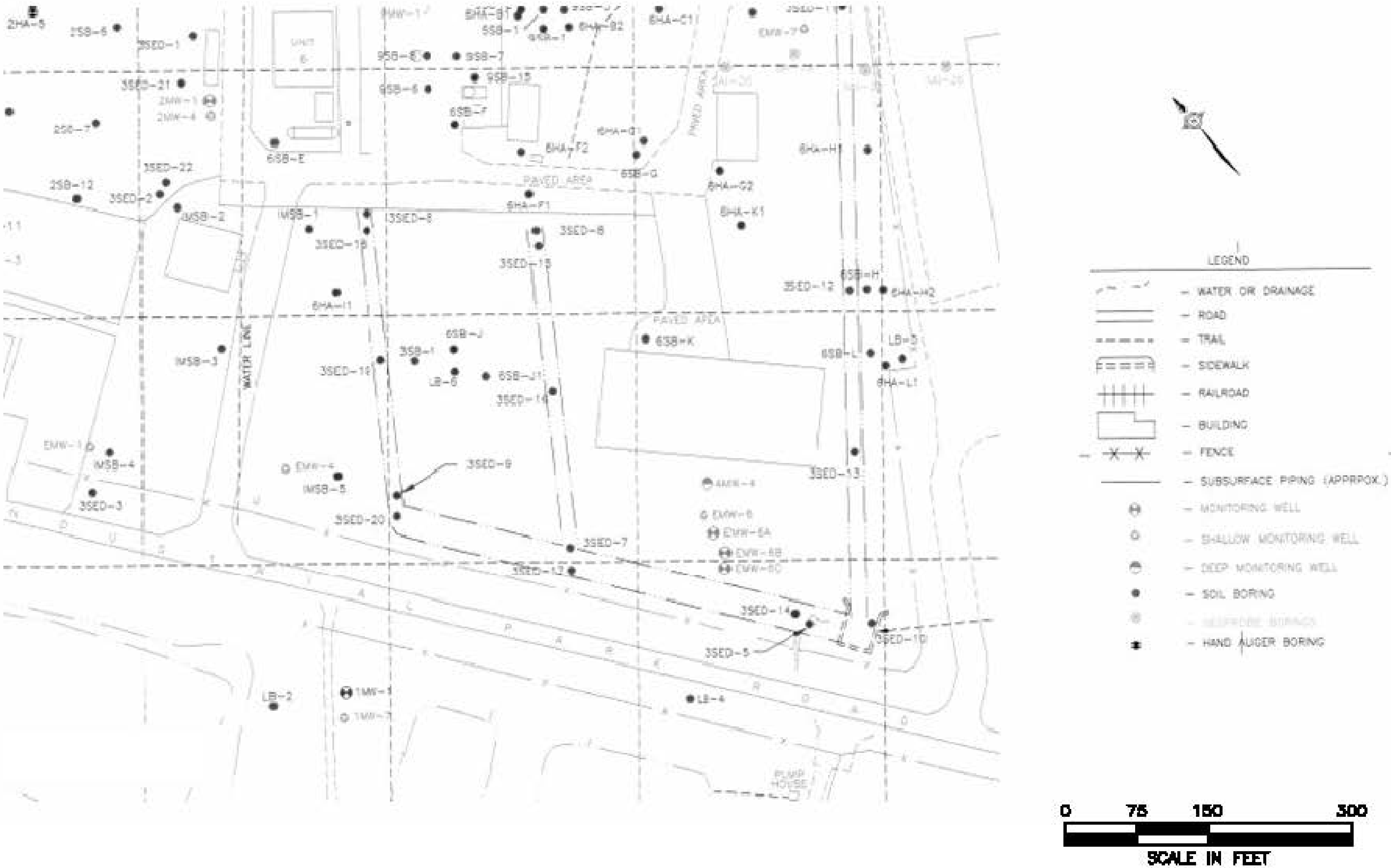
FIGURE 2-2
FACILITY LAYOUT MAP

FORMER CEDAR CHEMICAL FACILITY
HELENA - WEST HELENA, ARKANSAS

JUNE 2009

104336

L:\work\104336\CADD\104336_019 Facility Layout Map.dwg, 6/25/2009 10:21:33 AM, mandy.splawn



NOTE:

FIGURE WAS TAKEN FROM FIGURE E-1 OF THE 1996 FACILITY INVESTIGATION REPORT (ENSAFE, INC. 1996)

AECOM

FIGURE 3-1
HISTORIC SOIL SAMPLE LOCATION MAP AT SITE 3

FORMER CEDAR CHEMICAL FACILITY
HELENA - WEST HELENA, ARKANSAS

JUNE 2009

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L:\work\104336\CADD\104336_017 Historic Soil Sample Location Map.dwg, 5/26/2009 10:17:28 AM, mandy.sphere

LEGEND:

MW-19 ● MONITORING WELL LOCATION

TSB-1 ▲ TYCO 2009 SOIL BORING LOCATION

[44.2] DINOSEB CONCENTRATION IN SUBSURFACE SOIL - 4 TO 8 FEET BGS (mg/kg)

NOTES:

BGS - BELOW GROUND SURFACE

mg/kg - MILLIGRAMS PER KILOGRAM

MCL - MAXIMUM CONTAMINANT LEVEL

MSL - MEDIUM-SPECIFIC SCREENING LEVEL

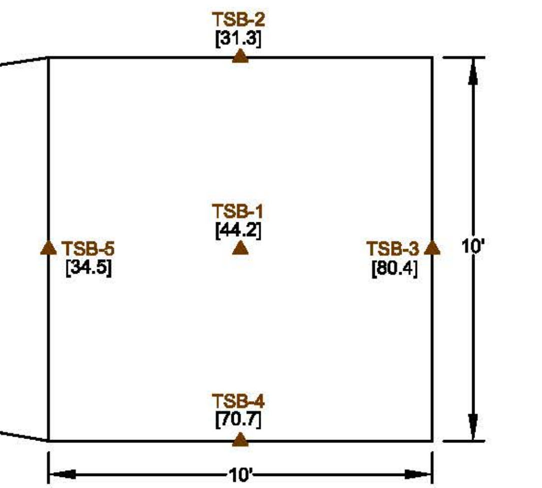
NAD83 - NORTH AMERICAN DATUM 1983

SSL - SOIL SCREENING LEVEL

1. THE EPA REGION 6 MSL FOR DINOSEB IN INDUSTRIAL SOIL IS 620 mg/kg.
2. THE EPA REGION 6 MCL-BASED SSL FOR DINOSEB IS 0.051 mg/kg.
3. THE HIGH RESOLUTION COLOR IMAGERY WAS OBTAINED FROM TERRASERVER-USA USING GLOBAL MAPPER SOFTWARE.
4. SITE 3 INCLUDES THE STORMWATER DITCHES AND SURROUNDING SOIL.

	HORIZONTAL SURVEY COORDINATES	
SOIL BORING ID	NORTHING	EASTING
TSB-1	1989250.59	1718138.22
TSB-2	1989254.56	1718141.32
TSB-3	1989247.54	1718142.13
TSB-4	1989246.52	1718135.13
TSB-5	1989253.86	1718134.28

ALL LOCATIONS ARE REFERENCED TO ARKANSAS STATE PLANE COORDINATE SYSTEM NAD83.



SCALE: EXAGGERATION x20

0 60 120 240

SCALE IN FEET

AECOM

FIGURE 3-2
RESULTS FOR DINOSEB IN SUBSURFACE SOIL (4 TO 8 FEET BGS) AT SITE 3

FORMER CEDAR CHEMICAL FACILITY
HELENA - WEST HELENA, ARKANSAS

JUNE 2009

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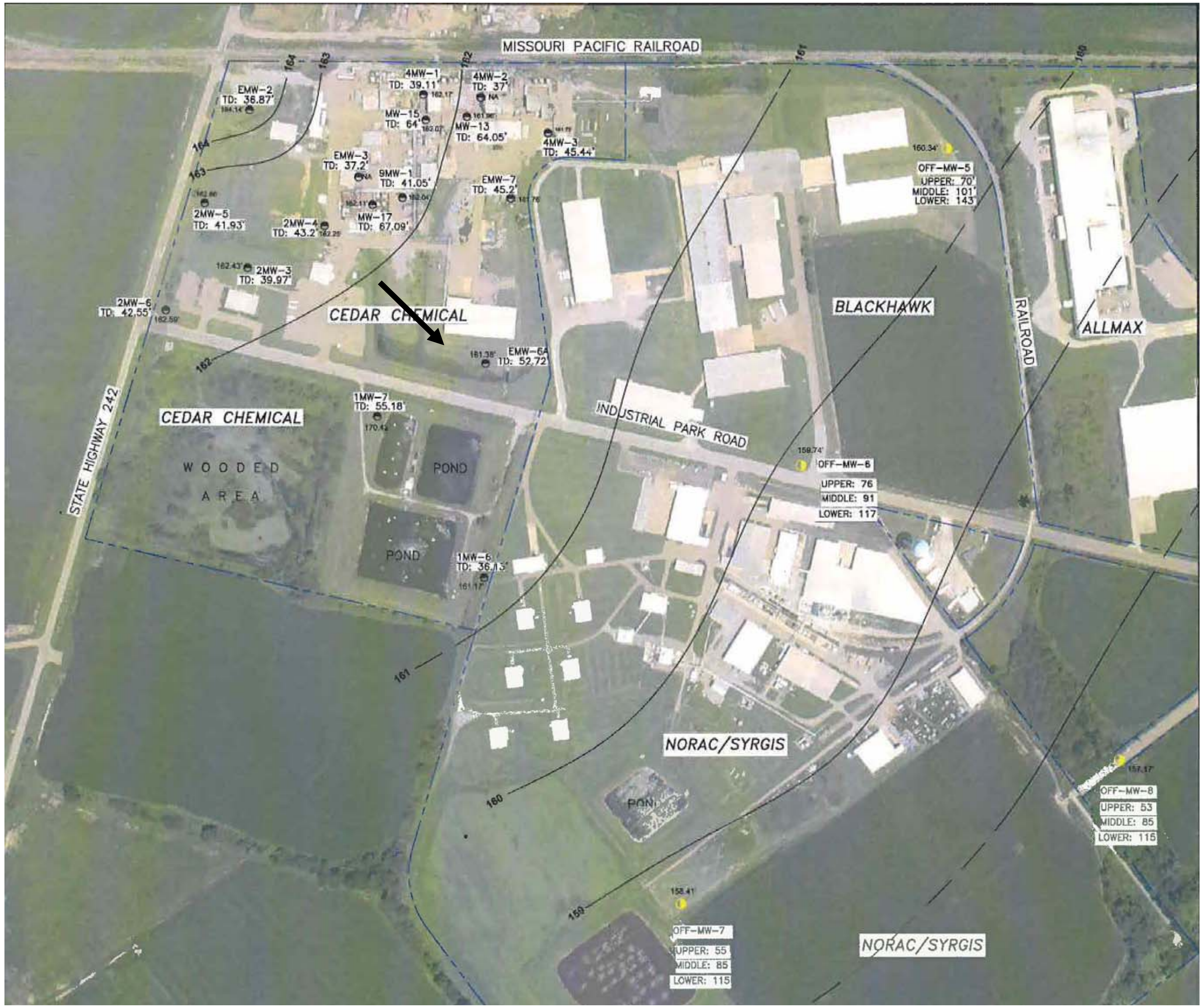
L:\work\104336\CADD\104336_015 Results for Dinoseb In Subsurface Soil at Site 3-June2009.dwg, 6/25/2009 10:19:37 AM, mandy.splawn



NOTE: Modified from Figure 10 of the Facility Investigation Report (AMEC Geomatrix, Inc., February 2009)

AECOM

FIGURE 3-3
POTENTIOMETRIC MAP
UPPER ALLUVIAL AQUIFER JULY 2008

FORMER CEDAR CHEMICAL FACILITY
HELENA-WEST HELENA, ARKANSAS

JUNE 2009

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NOTE: Modified from Figure 11 of the Facility Investigation Report (AMEC Geomatrix, Inc., February 2009)

AECOM

FIGURE 3-4
POTENTIOMETRIC MAP
UPPER ALLUVIAL AQUIFER SEPTEMBER 2008

FORMER CEDAR CHEMICAL FACILITY
HELENA-WEST HELENA, ARKANSAS

JUNE 2009

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LEGEND:

- MW-19 ● MONITORING WELL LOCATION
- TSB-1 ▲ TYCO 2009 SOIL BORING LOCATION
- STORMWATER DITCHES
- PROPERTY BOUNDARY
- ESTIMATED AREA FOR SOIL REMEDIAL MEASURES (11,306 SQUARE FEET)

NOTES:

1. AREA FOR SOIL REMEDIAL MEASURES WAS ESTIMATED BASED ON SOIL SAMPLES COLLECTED DURING THE 2009 WORMALD SITE INVESTIGATION (AECOM, 2009) AND THE 1996 FACILITY INVESTIGATION (ENSAFE, INC., 1996). SOIL SAMPLE RESULTS WERE USED TO APPROXIMATE THE AREA WHERE DINOSEB CONCENTRATIONS EXCEED SITE-SPECIFIC REMEDIAL GOAL OPTIONS (RGOs).
2. THE HIGH RESOLUTION COLOR IMAGERY WAS OBTAINED FROM TERRASERVER-USA USING GLOBAL MAPPER SOFTWARE.

0 60 120 240

SCALE IN FEET

AECOM

FIGURE 4-1
ESTIMATED AREA FOR SOIL REMEDIAL MEASURES AT SITE 3

FORMER CEDAR CHEMICAL FACILITY
HELENA - WEST HELENA, ARKANSAS

JUNE 2009

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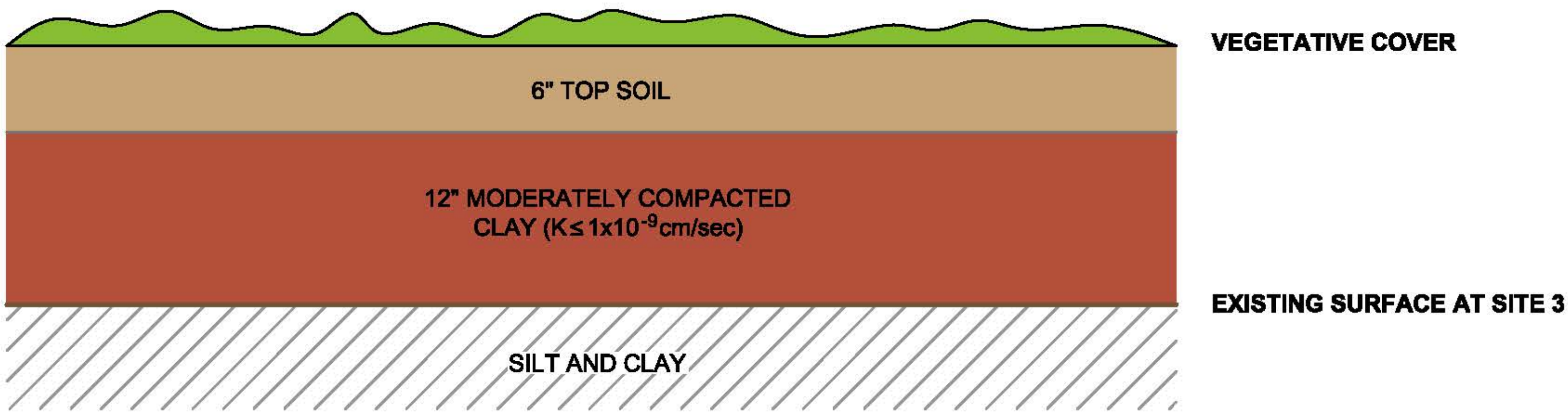
L:\work\104336\CADD\104336_018 Estimated Area for Soil Remedial Measures-Site 3.dwg, 6/25/2009 10:15:39 AM, mandy.splawn



NOT TO SCALE

AECOM

FIGURE 6-1
SCHEMATIC FOR ALTERNATIVE #4
ENGINEERED BARRIER

FORMER CEDAR CHEMICAL FACILITY
HELENA - WEST HELENA, ARKANSAS

JUNE 2009

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L:\work\104336\CADD\104336_016 Schematic for Alt 4 Engineered Barrier.dwg, 6/25/2009 10:18:23 AM, mandy.splawn

TABLES

TABLE ES-1
Comparative Analysis Summary for Remediation Alternatives
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Institutional Controls with Down-Gradient Groundwater Monitoring	Alternative 4 Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring
Overall Protectiveness	No reduction in risk to human health of future on-Site construction worker Natural attenuation mechanisms will reduce dinoseb concentrations over time Does not include ICs to ensure future land use remains industrial Least protective alternative	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial Includes groundwater sampling to monitor concentrations in groundwater down-gradient of Site 3; however, F&T modeling and groundwater sampling results indicate no risk to down-gradient receptors of alluvial aquifer groundwater due to residual dinoseb concentrations in soil at Site 3	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial Includes groundwater sampling to monitor concentrations in groundwater down-gradient of Site 3 and a low-permeability cap to reduce infiltration in soils impacted with dinoseb at Site 3; however, F&T modeling and groundwater sampling results indicate no risk to down-gradient receptors of alluvial aquifer groundwater due to residual dinoseb concentrations in soil at Site 3
Compliance with ARARs and Other Criteria, Advisories, and Guidance	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Does not meet or address the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3
Long-Term Effectiveness and Permanence	Includes no controls for potential exposure of on-Site future construction worker Includes no long-term management measures 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative
Reduction of Toxicity, Mobility, or Volume Through Treatment	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes Groundwater monitoring may provide an additional layer of protection for potential down-gradient receptors of alluvial aquifer groundwater; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater	This alternative provides no reduction in toxicity or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes Mobility of dinoseb may be reduced along the soil to groundwater pathway due to reduction in the infiltration rate by the engineered barrier and groundwater monitoring may provide an additional layer of protection for potential down-gradient receptors of alluvial aquifer groundwater; however, F&T modeling indicates that residual concentrations of dinoseb in soil at Site 3 do not pose a risk to alluvial aquifer groundwater

TABLE ES-1
Comparative Analysis Summary for Remediation Alternatives
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Institutional Controls with Down-Gradient Groundwater Monitoring	Alternative 4 Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring
Short-Term Effectiveness	This alternative does not provide any reduction in risk, including risk to the future on-Site construction worker Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Groundwater monitoring could be implemented in a short time period to monitor potential migration of dinoseb to alluvial aquifer groundwater; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Groundwater monitoring could be implemented in a short time period to monitor potential migration of dinoseb to alluvial aquifer groundwater and the infiltration rate could be reduced in a short period upon implementation of the engineered barrier; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3
Implementability	There are no implementability concerns with this alternative as no action will be taken	There are no technical implementation issues associated with ICs.	There are no technical implementation issues associated with ICs or with conducting groundwater sampling events	There are no technical implementation issues associated with ICs or with conducting groundwater sampling events The topography and layout of Site 3 is favorable for access with construction equipment and conventional construction equipment and materials could be used to construct the engineered barrier
Cost				
First Year	$0	$2,490	$9,149	$31,740
Present Worth	$7,008	$28,866	$73,298	$95,889

Notes:
Gray shading indicates the preferred alternative.
ARARs - Applicable or Relevant and Appropriate Requirements
F&T - fate and transport
ICs - institutional controls
MCL - maximum contaminant level
MWs - monitoring wells
RGO - remedial goal option

TABLE 3-1
Summary of Dinoseb Results in Soil at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Consultant	Matrix	Sample Identification	Sample Location	SBD (ft BGS)	SED (ft BGS)	Date Collected	Dinoseb Concentration (mg/kg)	Analytical Method	Analysis Date
EnSafe	Soil	3SB-1 (4-6')	3SB-1	4	6	NA	180	NA	9/29/1995
EnSafe	Soil	3SB-1 (6-12')	3SB-1	6	12	NA	0.63	NA	9/29/1995
EnSafe	Soil	3SB-6 (4-8')	LB-6	4	8	NA	**13000**	NA	1/10/1995
EnSafe	Soil	3SB-6 (8-12')	LB-6	8	12	NA	180	NA	1/10/1995
EnSafe	Soil	3SB-6 (12-16')	LB-6	12	16	NA	560	NA	1/10/1995
AECOM	Soil	TSB-1	TSB-1	4	8	3/5/2009	44.2	8151A	3/19/2009
AECOM	Soil	TSB-2	TSB-2	4	8	3/5/2009	31.3	8151A	3/19/2009
AECOM	Soil	TSB-3	TSB-3	4	8	3/5/2009	80.4	8151A	3/19/2009
AECOM	Soil	TSB-4	TSB-4	4	8	3/5/2009	70.7	8151A	3/19/2009
AECOM	Soil	TSB-5	TSB-5	4	8	3/5/2009	34.5	8151A	3/19/2009

Notes:

Bold font and shading indicates the result exceeds EPA Region 6 MSL for Dinoseb in Industrial Soil (620 mg/kg).
SBD - Sample Beginning Depth
SED - Sample Ending Depth
ft BGS - feet Below Ground Surface
mg/kg - milligrams per kilogram
NA - Not available

TABLE 3-2
Physical and Chemical Properties of Dinoseb at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Parameter	Value	Units	Source
Water solubility	52	mg/L	EPA Region 6 default value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Air diffusion coefficient	0.0215	cm^2/sec	SEVIEW chemical database (Environmental Software Consultants, Inc., 2006)
Henry's Law constant	4.56E-07	m^3-atm/mol	EPA Region 6 default value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Molecular weight	240.24	g/mole	SEVIEW chemical database (Environmental Software Consultants, Inc., 2006)
Organic carbon adsorption coefficient (Koc)	3544	mL/g	EPA Region 6 default value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Solid phase biodegradation rate	1.10E-03	1/day	based on site data
Liquid phase biodegradation rate	not included	1/day	NA
Distribution coefficient (Kd)	7.08E-03	m^3/kg	Koc x organic carbon; assume 0.2% organic carbon
Water diffusion coefficient	2.38E-06	m^2/hr	SEVIEW chemical database (Environmental Software Consultants, Inc., 2006)

Notes:

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., Michalenko, E.M. 1991. Handbook of Environmental Degradation Rates. Lewis Publishers, Inc. Chelsea, MI.

Environmental Software Consultants, Inc., January 2006. SEVIEW©: Integrated Contaminant Transport and Fate Modeling System, User’s Guide for Microsoft Windows®. Version 6.3 January 2006.

cm2/sec - square centimeters per second

g/mole - Grams per mole

mg/L - Milligrams per Liter

m^2/hr - Square meters per hour

m^3-atm/mol - Atmospheres-cubic meter per mole

m^3/kg - Cubic meters per kilogram

mL/g - Milliliters per gram

NA - Not Available

TABLE 3-3
Summary of SESOIL/AT123D Modeling Results for Dinoseb at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Scenario	Model Input: Soil Concentration[1] (mg/kg)	Model Input: Degradation Rate[2] (1/day)	Model Input: Distance X from Site 3[3] (m)	Model Output: Simulated Maximum Groundwater Concentration at Distance X (mg/L)	Model Output: Simulated Time to Reach Maximum at Distance X (years)
1	5.41E+07	0.011	NA	7.09E-13	978
2	0.62	None	300 [4]	7.15E-03	337
3	5.4	None	189 [4]	7.06E-03	330
4	5.41E+07	None	300 [4]	0	NA[5]
5	5.41E+07	None	189 [4]	5.77E-03	954

Notes:

1. This is the soil concentration input into the 4-8 foot depth interval of the SESOIL model and represents the area of residual dinsoeb concentrations in subsurface soil at Site 3.
The maximum soil concentration that can be input into SESOIL is 5.4 g/g (5.4E+07 mg/kg). This input value is much greater than concentrations detected in March 2009 (range of 31.3 mg/kg to 81.4 mg/kg) or concentrations from the 1996 FI (range of 0.63 mg/kg to 13,000 mg.kg) and was used as a conservative input for scenarios 1, 4, and 5. Soil concentration values for scenarios 2 and 3 were calculated through an iterative approach and represent the modeled maximum soil concentrations which results in groundwater concentrations below the MCL directly beneath the source.
2. The degradation rate was calculated based on Site-specific data from Site 3.
3. For each scenario, the model is used to predict the maximum alluvial aquifer groundwater concentration at a distance, X, from the area of residual dinoseb concentrations at Site 3. This distance is 0 m for groundwater concentrations directly beneath Site 3 (Scenario 1), and 300 m or 189 m for modeled concentrations at the Facility Property boundary (Scenarios 2 through 5).
4. Potentiometric contour maps provided in the Facility Investigation Report (AMEC Geomatrix, 2009) indicate a seasonal effect on gradient and groundwater flow direction. These maps were used to calculated hydraulic gradients in the vicinity of the Site 3 area for July 2008 (0.00097 ft/ft) and September 2008 (0.00013 ft/ft). The resulting gradients and flow direction yield a distance to the Facility boundary of 189 meters for the 0.00097 ft/ft gradient and 300 meters for the 0.00013 ft/ft gradient).
5. For Scenario 4, the modeled concentration at the Facility Property boundary is 0 mg/L through the maximum simulation time of 999 years.

m - Meters
mg/kg - Milligrams per kilogram
mg/L - Milligrams per Liter

TABLE 3-4
Summary of Groundwater Sampling Results for Monitoring Wells Down-Gradient of Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Sample Name	Aquifer	Consultant	Date Collected	Analysis Date	Dinoseb Concentration (ug/L)	Analytical Method
1MW-1	Perched Zone	EnSafe	NA	9/14/1993	ND	NA
1MW-1	Perched Zone	EnSafe	NA	11/29/1994	ND	NA
1MW-1	Perched Zone	EnSafe	NA	4/11/2001	ND	NA
1MW-1	Perched Zone	EnSafe	NA	7/25/2001	ND	NA
1MW-1	Perched Zone	Geomatrix	1/15/2008	1/22/2008	ND	8151A
1MW-1	Perched Zone	Geomatrix	1/15/2008	1/31/2008	ND	8270C
1MW-1	Perched Zone	Geomatrix	7/9/2008	7/16/2008	ND	8151A
1MW-1	Perched Zone	Geomatrix	7/9/2008	7/17/2008	ND	8270C
1MW-1	Perched Zone	Geomatrix	9/25/2008	10/3/2008	ND	8270C
1MW-1	Perched Zone	Geomatrix	9/25/2008	10/7/2008	ND	8151A
1MW-7	Alluvial Aquifer	EnSafe	NA	1/13/1995	ND	NA
1MW-7	Alluvial Aquifer	EnSafe	NA	4/11/2001	ND	NA
1MW-7	Alluvial Aquifer	EnSafe	NA	7/25/2001	ND	NA
1MW-7	Alluvial Aquifer	Geomatrix	1/14/2008	1/22/2008	ND	8151A
1MW-7	Alluvial Aquifer	Geomatrix	1/14/2008	2/6/2008	ND	8270C
1MW-7	Alluvial Aquifer	Geomatrix	7/10/2008	7/16/2008	ND	8151A
1MW-7	Alluvial Aquifer	Geomatrix	7/10/2008	7/17/2008	ND	8270C
1MW-7	Alluvial Aquifer	Geomatrix	9/25/2008	10/3/2008	ND	8270C
1MW-7	Alluvial Aquifer	Geomatrix	9/25/2008	10/7/2008	ND	8151A
4MW-4	Alluvial Aquifer	EnSafe	NA	1/20/1995	ND	NA
4MW-4	Alluvial Aquifer	EnSafe	NA	4/13/2001	ND	NA
4MW-4	Alluvial Aquifer	EnSafe	NA	7/24/2001	ND	NA
4MW-4	Alluvial Aquifer	Geomatrix	1/14/2008	1/22/2008	0.5 J	8151A
4MW-4	Alluvial Aquifer	Geomatrix	1/14/2008	2/6/2008	ND	8270C
4MW-4	Alluvial Aquifer	Geomatrix	7/8/2008	7/16/2008	0.54 J	8151A
4MW-4	Alluvial Aquifer	Geomatrix	7/8/2008	7/17/2008	ND	8270C
4MW-4	Alluvial Aquifer	Geomatrix	9/23/2008	10/1/2008	ND	8270C
4MW-4	Alluvial Aquifer	Geomatrix	9/23/2008	10/7/2008	1.1	8151A
EMW-6	Alluvial Aquifer	EnSafe	NA	9/24/1993	ND	NA
EMW-6	Alluvial Aquifer	EnSafe	NA	11/30/1994	ND	NA
EMW-6	Alluvial Aquifer	Geomatrix	1/9/2008	1/18/2008	ND	8151A
EMW-6	Alluvial Aquifer	Geomatrix	1/9/2008	1/18/2008	ND	8270C
EMW-6	Alluvial Aquifer	Geomatrix	7/9/2008	7/16/2008	0.49 J	8151A
EMW-6	Alluvial Aquifer	Geomatrix	7/9/2008	7/17/2008	ND	8270C
EMW-6	Alluvial Aquifer	Earth Tech	7/9/2008	7/18/2008	0.468 J	8151A
EMW-6	Alluvial Aquifer	Geomatrix	9/23/2008	10/1/2008	ND	8270C
EMW-6	Alluvial Aquifer	Geomatrix	9/23/2008	10/7/2008	ND	8151A
EMW-6A	Alluvial Aquifer	EnSafe	NA	9/24/1993	ND	NA
EMW-6A	Alluvial Aquifer	EnSafe	NA	11/30/1994	ND	NA
EMW-6A	Alluvial Aquifer	Geomatrix	1/9/2008	1/18/2008	0.29 J	8151A
EMW-6A	Alluvial Aquifer	Geomatrix	1/9/2008	1/18/2008	ND	8270C
EMW-6A	Alluvial Aquifer	Geomatrix	7/9/2008	7/16/2008	2.9 J	8151A
EMW-6A	Alluvial Aquifer	Geomatrix	7/9/2008	7/17/2008	ND	8270C
EMW-6A	Alluvial Aquifer	Geomatrix	9/23/2008	10/1/2008	ND	8270C
EMW-6A	Alluvial Aquifer	Geomatrix	9/23/2008	10/7/2008	1.8	8151A
EMW-6B	Perched Zone	EnSafe	NA	9/24/1993	ND	NA
EMW-6B	Perched Zone	EnSafe	NA	11/30/1994	ND	NA
EMW-6B	Perched Zone	Geomatrix	1/9/2008	1/18/2008	ND	8151A
EMW-6B	Perched Zone	Geomatrix	1/9/2008	1/18/2008	ND	8270C
EMW-6B	Perched Zone	Geomatrix	7/8/2008	7/16/2008	0.87 J	8151A
EMW-6B	Perched Zone	Geomatrix	7/8/2008	7/17/2008	ND	8270C
EMW-6B	Perched Zone	Geomatrix	9/23/2008	10/1/2008	ND	8270C
EMW-6B	Perched Zone	Geomatrix	9/23/2008	10/7/2008	1.1 J	8151A

TABLE 3-4
Summary of Groundwater Sampling Results for Monitoring Wells Down-Gradient of Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Sample Name	Aquifer	Consultant	Date Collected	Analysis Date	Dinoseb Concentration (ug/L)	Analytical Method
EMW-6C	Perched Zone	Geomatrix	1/9/2008	1/18/2008	ND	8151A
EMW-6C	Perched Zone	Geomatrix	1/9/2008	1/30/2008	**110 J**	8270C
EMW-6C	Perched Zone	Geomatrix	7/8/2008	7/16/2008	0.61 J	8151A
EMW-6C	Perched Zone	Geomatrix	7/8/2008	7/17/2008	ND	8270C
EMW-6C	Perched Zone	Geomatrix	9/23/2008	10/1/2008	ND	8270C
EMW-6C	Perched Zone	Geomatrix	9/23/2008	10/7/2008	ND	8151A

Notes:

1. Results were compiled from the 1996 and 2009 Facility Investigation Reports (EnSafe, Inc., 1996; AMEC Geomatrix, 2009). Earth Tech results are from split samples collected during the Facility Investigation conducted by AMEC Geomatrix.
2. Bold font and shading indicates the result exceeds the MCL for dinoseb (7 ug/L).

J - The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
ug/L - Microgram per Liter
MCL - Maximum contaminant level
NA - not available

TABLE 4-1
Potential Location-Specific ARARs at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Site Feature/Location	Citation	Requirement Synopsis	Consideration in this FS
Federal			
Within flood plain	Protection of floodplains (40 CFR 6, Appendix A); Fish and Wildlife Coordination Act (16 USC 661 et seq.); 40 CFR 6.302; Flood plains Executive Order (EO 11988)	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values; applies to action that will occur in a flood plain (i.e., lowlands) and relatively flat areas adjoining inland and coastal waters and other flood prone areas.	Not an ARAR since Site is not in a flood plain.
Within area where action may cause irreparable harm, loss or destruction of significant artifacts	National Historical Preservation Act (16 USC Section 469); 36 CFR Part 65	Required that action be taken to recover and preserve artifacts when alteration of terrain threatens significant scientific, prehistorical, historical, or archaeological data.	Not an ARAR since Site is not a designated archaeological area.
Critical habitat upon which endangered species or threatened species depends	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR Part 200, 50 CFR Part 402; Fish and Wildlife Coordination Act (16 USC 661 et seq.); 33 CFR Parts 320-330	If endangered or threatened species are present, action must be taken to conserve endangered or threatened species, including consultation with the Department of Interior.	Not an ARAR since Site does not have endangered or threatened species.
Wetlands	Clean Water Action Section 404; 40 CFR Part 230, 33 CFR Parts 320-330	For wetlands (as defined by U.S. Army Corps of Engineers regulations), must take action to prohibit discharge of dredged or fill material into wetlands without permit.	Not an ARAR since Site in not located within a wetland.
	40 CFR Part 6, Appendix A	For action involving construction of facilities or management of property in wetlands (as defined by 40 CFR Part 6, Appendix A, section 4(j)), action must be taken to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands, to the extent possible.	Not an ARAR since Site is not located within a wetland.

TABLE 4-1
Potential Location-Specific ARARs at Site 3
Former Cedar Chemicals Facility
Helena-West Helena, Arkansas

Site Feature/Location	Citation	Requirement Synopsis	Consideration in this FS
Federal			
Wilderness area	Wilderness Act (16 USC 1131 et seq.); 50 CFR 35.1 et seq.	For Federally-owned area designated as wilderness area, the area must be administered in such a manner as will leave it unimpaired as wilderness and to preserve its wilderness.	Not an ARAR since Site is not in a wilderness area.
Within area affecting national wild, scenic, or recreational river	Wild and Scenic Rivers Act (16 USC 1271 et seq.); Section 7(a)); 40 CFR 6.302(e)	For activities that affect or may affect any of the rivers specified in section 1271(a), must avoid taking or assisting in action that will have direct adverse effect on scenic river.	Not an ARAR since Site is not on or near a scenic river.
State			
Within 100-year flood plain	APCEC Reg. 22.503	Facility located within a 100-year flood plain must demonstrate that the unit will not restrict the flow, reduce the temporary water storage capacity of the floodplain, or result in washout of any waste materials.	Not an ARAR since Site is not in a 100-year flood plain.
Wetlands	APCEC Reg. 22.504	Facility must not be located in a wetland.	Not an ARAR since Site is not located within a wetland.

NOTES:
APCEC – Arkansas Pollution Control and Ecology Commission
ARAR – Applicable or Relevant and Appropriate Requirements
CFR – Code of Federal Regulations
EO – Executive Order
FS – Feasibility Study
USC – United States Code

TABLE 5-1
Identification and Screening of Potential Remediation Technologies at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Media	Constituent	Technology	Effectiveness	Implementability	Costs	Results of Technology Screening	Comments
Soil	Dinoseb	No Action	No	Yes	Lowest	Retained	Retained for baseline comparison of other technologies.
Soil	Dinoseb	Institutional Controls	Yes	Yes	Low	Retained	Effective in controlling exposure to site worker.
Soil and Groundwater	Dinoseb	Institutional Controls and Down-Gradient Groundwater Monitoring	Yes	Yes	Moderate	Retained	Effective in controlling exposure to site worker; groundwater monitoring may provide additional protection for potential off-Site groundwater receptors.
Soil and Groundwater	Dinoseb	Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring	Yes	Yes	Highest	Retained	Effective in controlling exposure to site worker; groundwater monitoring may provide additional protection for potential off-Site groundwater receptors; engineered barrier may reduce the infiltration rate.

TABLE 6-1
Cost Estimate Summary for Alternative 1
No Action
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Total First Year Capital Cost	**Unit**	**Unit Cost**	**Cost**
Total First Year Estimated Cost	NA	-	$0
Present Value Cost	**Unit**	**Unit Cost**	**Cost**
Includes:			
Present Value Discount Rate*	3%		
Total First Year Cost	0	$0	$0
Task 01: 5-Year Remedy Review; Years 5 and 10	2	$4,326	$7,008
Total Present Value Cost			**$7,008**

Assumptions:

Task 01 includes the following:

Labor to generate 5-Year Remedy Review documentation
Site inspection, photo documentation
Regulation review
Agency submittal

* - Present Value discount rate, defined as the "real discount rate" that has been adjusted to account for the effect of expected or actual inflation (escalation). Therefore, the Present Value Discount Rate = Nominal Discount/Interest Rate (7%) - Inflation Rate (4%) = 3%

TABLE 6-2
Cost Estimate Summary for Alternative 2
Institutional Controls
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Total First Year Capital Cost	**Unit**	**Unit Cost**	**Cost**
Task 01: Remedy Review - Year 1	0	$0	$0
Task 02A : Institutional Controls Implementation	1	$2,490	$2,490
Task 02B: Institutional Controls O&M - Year 1	0	$0	$0
Total First Year Estimated Cost			**$2,490**
Present Value Cost	**Unit**	**Unit Cost**	**Cost**
Includes:			
Present Value Discount Rate*	3%		
Total First Year Cost	1	$2,490	$2,490
Task 01: 5-Year Remedy Review; Years 5 and 10	2	$4,326	$7,008
Task 02B: Institutional Controls O&M - Years 2 through 10	9	$2,546	$19,368
Total Present Value Cost			**$28,866**

Assumptions:

Task 01 includes the following:

- Labor to generate 5-Year Remedy Review documentation
- Site inspection, photo documentation
- Regulation review
- Agency submittal

Task 02A includes the following:

- Preparing deed restriction
- Filing deed restriction

Task 02B includes the following:

- Mob of Personnel to Site for annual inspection of fencing
- Annual fence inspection & repair (years 2 - 10)

* - Present Value discount rate, defined as the "real discount rate" that has been adjusted to account for the effect of expected or actual inflation (escalation). Therefore, the Present Value Discount Rate = Nominal Discount/Interest Rate (7%) - Inflation Rate (4%) = 3%

TABLE 6-3

Cost Estimate Summary for Alternative 3

Institutional Controls with Down-Gradient Groundwater Monitoring

Former Cedar Chemical Facility

Helena – West Helena, Arkansas

Total First Year Capital Cost	**Unit**	**Unit Cost**	**Cost**
Task 01: Remedy Review - Year 1	0	-	$0
Task 02A : Institutional Controls Implementation	1	$2,490	$2,490
Task 03: Annual Groundwater Monitoring - Year 1	1	$6,659	$6,659
Total First Year Estimated Cost			**$9,149**
Present Value Cost	**Unit**	**Unit Cost**	**Cost**
Includes:			
Present Value Discount Rate*	3%		
Total First Year Cost	1	$9,149	$9,149
Task 01: 5-Year Remedy Review; Years 5 and 10	2	$4,326	$7,008
Task 03: Annual Groundwater Monitoring - Years 2 through 10	9	$6,659	$57,141
Total Present Value Cost			**$73,298**

Assumptions:

Task 01 includes the following:

- Labor to generate 5-Year Remedy Review documentation
- Site inspection, photo documentation
- Regulation review
- Agency submittal

Task 02A includes the following:

- Preparing deed restriction
- Filing deed restriction

Task 02B includes the following:

- Mob of Personnel to Site for annual inspection of fencing - included with Task 03
- Annual fence inspection & repair (years 2 - 10) - Included with Task 03

Task 03 includes the following:

- Annual sampling and reporting (years 1 - 10)
- Data validation, evaluation, and preparation of annual report (years 1 - 10)
- Number of wells sampled per even = 6 + 1 duplicate
- Field crew = 2 people
- Number of events = 10
- Sampling time per event = 3 days

* - Present Value discount rate, defined as the "real discount rate" that has been adjusted to account for the effect of expected or actual inflation (escalation). Therefore, the Present Value Discount Rate = Nominal Discount/Interest Rate (7%) - Inflation Rate (4%) = 3%

TABLE 6-4

Cost Estimate Summary for Alternative 4

Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring

Former Cedar Chemical Facility

Helena – West Helena, Arkansas

Total First Year Capital Cost	**Unit**	**Unit Cost**	**Cost**
Task 01: Remedy Review - Year 1	0	$0	$0
Task 02: Institutional Controls Implementation	1	$4,171	$4,171
Task 03: Annual Groundwater Monitoring - Year 1	1	$6,659	$6,659
Task 04: Engineered Barrier	1	$20,910	$20,910
Total First Year Estimated Cost			**$31,740**
Present Value Cost	**Unit**	**Unit Cost**	**Cost**
Includes:			
Present Value Discount Rate*	3%		
Total First Year Cost	1	$31,740	$31,740
Task 01: 5-Year Remedy Review; Years 5 and 10	2	$4,326	$7,008
Task 03: Annual Groundwater Monitoring - Years 2 through 10	9	$6,659	$57,141
Total Present Value Cost			**$95,889**

Assumptions:

Task 01 includes the following:
- Labor to generate 5-Year Remedy Review documentation
- Site inspection, photo documentation
- Regulation review
- Agency submittal

Task 02A includes the following:
- Preparing deed restriction
- Filing deed restriction

Task 02B includes the following:
- Mob of Personnel to Site for annual inspection of fencing - included with Task 03
- Annual fence inspection & repair (years 2 - 10) - Included with Task 03

Task 03 includes the following:
- Annual sampling and reporting (years 1 - 10)
- Data validation, evaluation, and preparation of annual report (years 1 - 10)
- Number of wells sampled per even = 6 + 1 duplicate
- Field crew = 2 people
- Number of events = 10
- Sampling time per event = 3 days

Task 04 includes the following:
- Installation of fill, topsoil, and hydro seeding
- Consultant oversight
- Annual mowing & trimming (years 1 - 10) - Included with Task 03
- Annual fence inspection & repair (years 1 - 10) - Included with Task 03
- Annual inspection - included in Task 03

* - Present Value discount rate, defined as the "real discount rate" that has been adjusted to account for the effect of expected or actual inflation (escalation). Therefore, the Present Value Discount Rate = Nominal Discount/Interest Rate (7%) - Inflation Rate (4%) = 3%

TABLE 6-5
Comparative Analysis Summary for Remediation Alternatives
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Institutional Controls with Down-Gradient Groundwater Monitoring	Alternative 4 Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring
Short-Term Effectiveness	This alternative does not provide any reduction in risk, including risk to the future on-Site construction worker Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Groundwater monitoring could be implemented in a short time period to monitor potential migration of dinoseb to alluvial aquifer groundwater; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	This alternative provides an immediate risk reduction to human health of future on-Site construction worker through use of ICs and will be effective immediately upon incorporation of the ICs Groundwater monitoring could be implemented in a short time period to monitor potential migration of dinoseb to alluvial aquifer groundwater and the infiltration rate could be reduced in a short period upon implementation of the engineered barrier; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3
Implementability	There are no implementability concerns with this alternative as no action will be taken	There are no technical implementation issues associated with ICs.	There are no technical implementation issues associated with ICs or with conducting groundwater sampling events	There are no technical implementation issues associated with ICs or with conducting groundwater sampling events The topography and layout of Site 3 is favorable for access with construction equipment and conventional construction equipment and materials could be used to construct the engineered barrier
Cost				
First Year	$0	$2,490	$9,149	$31,740
Present Worth	$7,008	$28,866	$73,298	$95,889

Notes:
Gray shading indicates the preferred alternative.
ARARs - Applicable or Relevant and Appropriate Requirements
F&T - fate and transport
ICs - institutional controls
MCL - maximum contaminant level
MWs - monitoring wells
RGO - remedial goal option

TABLE 6-5
Comparative Analysis Summary for Remediation Alternatives
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Institutional Controls with Down-Gradient Groundwater Monitoring	Alternative 4 Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring
Overall Protectiveness	No reduction in risk to human health of future on-Site construction worker Natural attenuation mechanisms will reduce dinoseb concentrations over time Does not include ICs to ensure future land use remains industrial Least protective alternative	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial Includes groundwater sampling to monitor concentrations in groundwater down-gradient of Site 3; however, F&T modeling and groundwater sampling results indicate no risk to down-gradient receptors of alluvial aquifer groundwater due to residual dinoseb concentrations in soil at Site 3	Reduces risk to human health of future on-Site construction worker through use of ICs Natural attenuation mechanisms will reduce dinoseb concentrations over time Includes ICs to ensure future land use remains industrial Includes groundwater sampling to monitor concentrations in groundwater down-gradient of Site 3 and a low-permeability cap to reduce infiltration in soils impacted with dinoseb at Site 3; however, F&T modeling and groundwater sampling results indicate no risk to down-gradient receptors of alluvial aquifer groundwater due to residual dinoseb concentrations in soil at Site 3
Compliance with ARARs and Other Criteria, Advisories, and Guidance	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Does not meet or address the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3	F&T modeling indicates residual dinoseb concentrations in soil at Site 3 do not pose a risk to potential receptors of alluvial aquifer groundwater; groundwater samples from alluvial aquifer MWs down-gradient of Site 3 have not exceeded the MCL in any sample since 1993 Addresses the soil RGO for direct exposure of the potential future construction worker to perched zone groundwater through the use of institutional controls Time to reach soil cleanup goal is approximately 10 years based on Site-specific degradation rate for dinoseb in subsurface soil at Site 3
Long-Term Effectiveness and Permanence	Includes no controls for potential exposure of on-Site future construction worker Includes no long-term management measures 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative	Includes ICs to control potential exposure of on-Site future construction worker Includes ICs to ensure land use remains industrial and limit unauthorized access 5-year remedy reviews may be required for this alternative
Reduction of Toxicity, Mobility, or Volume Through Treatment	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes	This alternative provides no reduction in toxicity, mobility, or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes Groundwater monitoring may provide an additional layer of protection for potential down-gradient receptors of alluvial aquifer groundwater; however, historic sampling results and F&T modeling indicate that residual concentrations of dinoseb in subsurface soil at Site 3 do not pose a risk to the alluvial aquifer groundwater	This alternative provides no reduction in toxicity or volume of dinoseb impacted soil through treatment Volume of dinoseb impacted soil will be reduced over time by natural processes Mobility of dinoseb may be reduced along the soil to groundwater pathway due to reduction in the infiltration rate by the engineered barrier and groundwater monitoring may provide an additional layer of protection for potential down-gradient receptors of alluvial aquifer groundwater; however, F&T modeling indicates that residual concentrations of dinoseb in soil at Site 3 do not pose a risk to alluvial aquifer groundwater

APPENDIX A

CHRONOLOGICAL LIST OF KEY DOCUMENTS

Chronological List of Key Documents
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

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Arkansas Department of Pollution Control and Ecology (ADPC&E), December 12, 1991. Memo to Cedar Chemical.

EnSafe, Inc., March 2, 1995. Facility Investigation, Cedar Chemical Company. (Phase I and II).

EnSafe, Inc., June 28, 1996. Facility Investigation, Cedar Chemical Company. (Phase I through III).

EnSafe, Inc., March 21, 2001. Risk Assessment-Cedar Chemical Corporation, West Helena, Arkansas.

EnSafe, Inc., January 22, 2002. Risk Assessment Addendum-Cedar Chemical Corporation, West Helena, Arkansas.

ADEQ, May 2003. Comprehensive Site Assessment-Cedar Chemical Corporation Plant Site. Revised April 2004.

United States Department of Health and Human Services, 2005. Health Consultation, Health Implications of Farm Workers Exposed to Groundwater Adjacent to Cedar Chemical Corporation.

ADEQ, August 23, 2005. Cedar Chemical Company: Request for Proposals Packet.

United States Department of Health and Human Services, 2006. Health Consultation Follow-Up Report on the Health Implications of Farm Workers Exposed to 1,2-DCA Contaminated Groundwater Adjacent to Cedar Chemical Corporation.

ADEQ, March 22, 2007. Consent Administrative Order LIS No. 07-027.

Geomatrix Consultants, Inc., November 2007. Current Conditions Report, Cedar Chemical Corporation Facility, Helena – West Helena, Arkansas.

Geomatrix Consultants, Inc., January 2008. Facility Investigation Workplan, Cedar Chemical Corporation Facility, Helena – West Helena, Arkansas.

Geomatrix Consultants, Inc., January 21, 2008. Fifth Monthly Status Report (December 1st to 31st, 2007), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

Geomatrix Consultants, Inc., February 11, 2008. Sixth Monthly Status Report (January 1st – 31st, 2008), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

Geomatrix Consultants, Inc., March 2008. Quality Assurance Project Plan, Cedar Chemical Corporation Facility, Helena – West Helena, Arkansas.

Chronological List of Key Documents
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Helena - West Helena, Arkansas

Geomatrix Consultants, Inc., March 2008. Site Health and Safety Plan, Cedar Chemical Corporation Facility, Helena – West Helena, Arkansas.

Geomatrix Consultants, Inc., March 17, 2008. Seventh Monthly Status Report (February 1st – 29th, 2008), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

Geomatrix Consultants, Inc., May 16, 2008. Ninth Monthly Status Report (April 1st – 30th, 2008), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

Geomatrix Consultants, Inc., May 27, 2008. Facility Investigation Work Plan Supplement, Perched and Alluvial Aquifer Monitoring Well Installation Program, Cedar Chemical Company Site.

AMEC Geomatrix, Inc., August 28, 2008. Facility Investigation (FI) Workplan Supplement No. 2, Installation of Additional Alluvial Aquifer Monitoring Wells, Cedar Chemical Company Facility ("the Site"),West Helena, Arkansas, State EPA ID No. ARD990660649.

AMEC Geomatrix, Inc., August 28, 2008. Facility Investigation (FI) Workplan Supplement No. 3, Interim Measure – Waste Removal for the Drum Vault, Cedar Chemical Company Facility ("the Site"),West Helena, Arkansas, State EPA ID No. ARD990660649.

ADEQ, September 12, 2008. Facility Investigation (FI) Workplan Supplement No. 3 – Interim Measure of Waste Removal from the Drum Vault for Cedar Chemical Company (August 28, 2008). EPA ID Number ARD990660649; AFIN 54-00068.

AMEC Geomatrix, Inc., September 18, 2008. Thirteenth Monthly Status Report (August 1st – 31st, 2008), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

AMEC Geomatrix, Inc., October 10, 2008. Fourteenth Monthly Status Report (September 1st – 30th, 2008), Cedar Chemical Company Facility ("the Site"), Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

AMEC Geomatrix, Inc., October 13, 2008. Interim Facility Investigation Report, Cedar Chemical Company Facility, Helena – West Helena, Arkansas.

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AECOM, January 22, 2009. Wormald Site Investigation Work Plan, Former Cedar Chemical Facility, Helena-West Helena, Arkansas, State EPA ID No. ARD990660659.

Chronological List of Key Documents
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Helena - West Helena, Arkansas

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AECOM, March 30, 2009. Wormald Site Investigation Report, Former Cedar Chemical Facility, Helena – West Helena, Arkansas.

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AECOM, April 27, 2009. Response to Comments on the Wormald Site Investigation Report, Former Cedar Chemical Facility, Helena – West Helena, Arkansas, State EPA No. ARD990660649.

AECOM, April 27, 2009. Revised Wormald Site Investigation Report, Former Cedar Chemical Facility, Helena – West Helena, Arkansas, State EPA No. ARD990660649.

ADEQ, May 4, 2009. Wormald Site Investigation Report for Cedar Chemical Company (April 27, 2009), EPA ID Number ARD990660649; AFIN 54-00068.

AECOM, May 21, 2009. Response to Comments on the Wormald Site Investigation Report (April 27, 2009), Former Cedar Chemical Facility, Helena – West Helena, Arkansas, State EPA ID No. ARD990660649.

ADEQ, May 26, 2009. Revised Wormald Site Investigation Report for Cedar Chemical Company and Response to Comments (May 22, 2009), EPA ID Number ARD990660649; AFIN 54-00068.

AECOM, May 28, 2009. Addendum to Response to Comments on the Wormald Site Investigation Report (April 27, 2009), Former Cedar Chemical Facility, Helena – West Helena, Arkansas, State EPA ID No. ARD990660649

AECOM, June 2, 2009. Revised Wormald Site Investigation Report – Surveyor Map, Former Cedar Chemical Facility, Helena – West Helena, Arkansas, State EPA No. ARD990660649

ADEQ, June 4, 2009. Response to ADEQ Comments Facility Investigation Report for Cedar Chemical Company (Project Number 013636); EPA ID Number ARD990660649; AFIN 54-00068.

AMEC Geomatrix, Inc., June 16, 2009. Final Response to Comments on the Facility Investigation (FI) Report for Former Cedar Chemical Company Facility (February 2009) and the ADEQ Approval of Response to Comments dated June 4, 2009, EPA ID Number AR990660649, AFIN 54-00068.

APPENDIX B

FATE AND TRANSPORT MODELING FOR SITE 3 USING SESOIL AND AT123D

Description of Fate and Transport Modeling Procedures

Appendix B
Fate and Transport Modeling for Site 3 Using SESOIL and AT123D

The goal of SESOIL/AT123D modeling for Site 3 was to obtain the maximum dinoseb concentration in subsurface soil at Site 3 that would not impact alluvial aquifer groundwater. The unsaturated (vadose) zone model SESOIL was used to evaluate the overall effects of degradation and other mechanisms on the transport of dinoseb through soil. SESOIL (Bonazountas and Wagner, 1984) was developed as a screening level model that uses less soil, chemical, and meteorological data than other, more complex models. The model uses actual climate data in the hydrological cycle predictions rather than a constant infiltration rate, which is common in other similar models. The SESOIL model can also accept constant infiltration rates. The model output can include time-varying constituent concentrations at different soil depths and removal of the constituent from the soil column by surface runoff, percolation to groundwater, volatilization, adsorption, and degradation. For this modeling, dinoseb was distributed among a dissolved, porewater phase, an adsorbed phase, and biodegraded dinoseb based on the assigned solubility, biodegradation rates, and distribution coefficients (Table B-1).

The concentration in leachate, derived from the SESOIL model, was used as input to the saturated zone model, AT123D (Yeh, 1981), to compute a resulting concentration in groundwater beneath the modeled location (Site 3) and downgradient at the Cedar Chemical Facility boundary. The AT123D model is used to predict resulting groundwater concentrations when pore water from the vadose zone mixes with water in the underlying aquifer. AT123D is an analytical groundwater transport model that computes the spatial-temporal concentration distribution of a constituent in the aquifer and predicts the transient spread of a chemical plume through an aquifer using advection, dispersion, adsorption, and decay. The decay function was not used in this model.

The SEVIEW© (Schneiker, 2006) program, which links SESOIL and AT123D, was used for modeling. SEVIEW© is a menu-driven, integrated contaminant modeling system that simplifies transport and fate modeling by linking the SESOIL vadose zone model to AT123D.

Input to SESOIL

Input parameters for SESOIL were derived directly or indirectly from Site-specific data, United States Environmental Protection Agency (USEPA) Region 6 default values, literature values, and SESOIL guidance. Input for chemical and soil properties and the source of the input are listed in Tables B-1 and B-2. The solid phase biodegradation rate (Table B-1) of 0.0011/day, developed using Site 3 analytical data, was used for modeling as it is more conservative than literature values (Table B-1). The model was also run without a soil degradation rate for comparison. A water degradation rate was not used for modeling. The soil pore disconnected index (Table B-2) relates soil permeability to soil moisture content. This parameter is specific to SESOIL and the value used was based on values recommended in SESOIL guidance for the soil type that is present at Site 3.

SESOIL contaminant extent data (Table B-3) are used by the model to define the three-dimensional volume of the soil column. An area of 100 square feet of residual dinoseb concentrations in soil at Site 3 was used for modeling based on the 10 x 10 square foot area sampled in March, 2009. This sample location was designed to be located where soil sample 3SB-6 (4 to 8 feet below ground surface (ft bgs)) had been obtained. The only other soil data for Site 3 are from 1995 samples at sol boring 3SB-1 that had dinoseb concentrations of 180 milligrams per kilogram (mg/kg) in the 4 to 6 ft bgs interval and 0.63 mg/kg in the 6 to 12 ft bgs interval. These concentrations are 2 percent or less of the 1995 3SB-6 concentration of 13,000 mg/kg. Assuming the degradation half-life of 630 days, calculated for Site 3, the soil concentration would presently be about 0.7 mg/kg.

SESOIL can include four vadose zone soil layers. For Site 3, the layers, which are summarized below, were defined based on Site 3 soil sample data and the log for boring 4MW4 from the Facility Investigation Report (EnSafe, Inc., 1996):

1. Ground surface to top of dinoseb-impacted soil – 0 to 4 ft bgs (based on the soil interval collected in March, 2009)
2. Dinoseb-impacted soil interval – 4 to 8 ft bgs (March, 2009 samples)
3. Bottom of dinoseb-impacted soil interval to top of clay semi-confining unit – 8 to 42 ft bgs (based on the log from 4MW-4); and
4. Clay layer / Semi-confining unit – 42 to 47 ft bgs (based on the log from 4MW-4).

The upper three layers were assigned an unsaturated hydraulic conductivity value of 7.6e-5 cm/sec based on the results of slug tests performed in wells closest to Site 3 (AMEC Geomatrix, 2009, Table 5; wells MW-16 and EMW-6B). A lower hydraulic conductivity of 1e-6 cm/sec was used for the clay layer. These values were converted to intrinsic permeability, used by the SESOIL model, by multiplying by 1e-5.

As part of the SEVIEW software, climatic data are provided for a number of stations that collect meteorological data, including a weather station from the Thompson-Robbins Helena airport. This station is located northwest of Helena-West Helena. The SEVIEW software integrates the appropriate meteorological data from the climatic data records. The input parameters for the climatic data include for each month: temperature, cloud cover, relative humidity, short wave albedo, evapotranspiration, precipitation, storm length, number of storms, and length of rainy season.

Input to AT123D

SESOIL models the concentrations in pore water at the bottom of the vadose zone (i.e., the bottom of Layer 4). To determine the concentration in groundwater, AT123D is used. SESOIL can model up to 999 years in monthly increments. The time-series concentrations developed by SESOIL are input to AT123D through the link in the SEVIEW software. Table B-4 lists other AT123D model parameters and their sources. AT123D input were based on site data and model guidance. AT123D assumes a homogeneous porous medium.

SESOIL/AT123D Model Method and Results

The goal of SESOIL/AT123D modeling for Site 3 was to obtain the maximum dinoseb concentration in subsurface soil at Site 3 that would not impact alluvial aquifer groundwater (i.e., would not result in dinoseb concentrations in alluvial aquifer groundwater that exceed the maximum contaminant level (MCL)). The U.S. EPA maximum contaminant level of 0.007 milligrams per liter (mg/L) was used as the target groundwater concentration in the alluvial aquifer. An initial soil concentration is input. If the resulting groundwater concentration exceeds 0.007 mg/L, a lower soil concentration is modeled; if the resulting groundwater concentration is less than 0.007 mg/L, a greater soil concentration is input.

The dinoseb concentrations were obtained by AT123D modeling were for three locations in groundwater:

- at the top of the water table and directly centered below dinoseb impacted soil at Site 3 (i.e., the locations of borings TSB-1 through TSB-5 from the 2009 Wormald Site Investigation (AECOM, May 2009));
- at the top of the alluvial aquifer 189 meters (m) downgradient of the dinoseb source; and
- at the top of the alluvial aquifer 300 m downgradient of the dinoseb source.

Two down-gradient locations were modeled because the groundwater hydraulic gradient differs seasonally due to pumping for irrigation. Water level measurements taken in July, 2008 (AMEC Geomatrix, 2009) were used to develop a gradient of 9.7e-4 meters per meter (m/m) and a resulting groundwater flow distance to the Cedar Chemical Facility boundary of 189 m. Water level measurements taken in September, 2008 (AMEC Geomatrix, 2009) were used to develop a gradient of 1.4e-4 m/m and a resulting groundwater flow distance to the Cedar Chemical site boundary of 300 m.

Table B-5 lists results of SESOIL/AT123D modeling. Also listed in the table are the times required for the pore water to reach the water table and to reach the maximum concentration in groundwater. Below the table is listed the hydrologic output of the SESOIL model:

- Evapotranspiration: 12.86 inches per year
- Groundwater recharge: 2.03 inches per year
- Soil moisture: 19.5 to 21.7 inches per year.

The maximum soil concentration that can be input into SESOIL is 5.4 grams per gram (g/g) soil. The model predicts that this concentration would not result in groundwater contamination directly below the contaminated soil at Site 3 if biodegradation is occurring at the rate modeled (0.0011/day). Groundwater contamination also would not result, even without biodegradation, at the Cedar Chemical Facility boundary under either groundwater flow gradient modeled. Although it is doubtful that biodegradation would occur if highly elevated concentrations of dinoseb were present, the modeling indicates that the current concentrations of dinoseb (average of 52.2 mg/kg) are not predicted to result in groundwater contamination of the alluvial aquifer.

The model was also run to evaluate soil concentrations needed to prevent groundwater exceedances of the 0.007 mg/L standard directly below the center of the contaminated area if no biodegradation was occurring. The model indicated that the soil contamination in the 4 to 8 ft bgs zone would need to be approximately 5.4 mg/kg or less under groundwater conditions measured in July 2008, or less than a milligram per liter under conditions measured in September 2008. However, the observed decrease in soil dinoseb concentrations, as well as scientific references, provide evidence that biodegradation is expected and appears to be occurring at Site 3.

Attached to this evaluation are tables and figures that contain input and output files for SESOIL/AT123D modeling runs listed in Table B-5. Files for each location are identified by the run file name and by the following terms:

- "load input" provides a summary of input parameters for the model run.
- "mass" provides the partitioning of the dinoseb mass, the maximum dinoseb concentration in pore water, and graphs of dinoseb distribution in the vadose zone with time (mass and concentration) and depth.
- "at123D" provides input parameters for AT123D, a graph of dinoseb concentrations with time, maximum groundwater concentration at the designated point (center of the mass at the top of the water table), and the year the maximum groundwater concentration is reached.

Two files are identical for the model runs. The file labeled "climate report" provides climate data in table and graph form. The file labeled "hydro" provides graphs and tables showing the division of precipitation into surface runoff and infiltration (upper figure). The lower figure (and the table) further subdivide infiltration into evapotranspiration, moisture retention (soil moisture), and groundwater runoff, which is the portion that recharges groundwater.

Summary of Fate and Transport

The dominant migration path for dinoseb at Site 3 is movement downward through the vadose zone and to groundwater. Comparison of soil concentrations indicates that biodegradation has reduced the concentration of dinoseb by over 99 percent since 1995. Modeling indicates that biodegradation will prevent residual concentrations of dinoseb in subsurface soil at Site 3 from impacting the alluvial groundwater. Even without biodegradation, the model predicts that dinoseb concentrations in the alluvial aquifer will not reach or exceed the MCL (0.007 mg/kg) at the Cedar Chemical Facility boundary.

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Stevens, T.O., Crawford, R.L., Crawford, D.L. 1991. Selection and isolation of bacteria capable of degrading dinoseb (2-sec-buty-4,6-dinitrophenol) in Biodegradation, vol. 2, p. 1-13.

Stevens, T.O., Crawford, R.L., Crawford, D.L. 1990. Biodegradation of Dinoseb (2-sec-Butyl-4,6-Dinitrophenol) in Several Idaho Soils with Various Dinoseb Exposure Histories in Applied and Environmental Microbiology, vol. 56, p. 133-139.

U.S. Environmental Protection Agency (EPA). 1996. Technical Factsheet on: Dinoseb. Factsheet was prepared as part of the National Primary Drinking Water Regulations and was last updated online Tuesday, November 28th, 2006. Accessed August 2008 at http://www.epa.gov/OGWDW/dwh/t-soc/dinoseb.html

U.S. National Library of Medicine (NLM). 2003. Hazardous Substances Data Base (HSDB): Dinoseb. Last revised February 2003. Accessed August 2008 at http://toxnet.nlm.nih.gov.

Yeh, G.T. 1981. AT123D: Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System. Tennessee. ORNL-5602.

Summary Tables

TABLE B-1
Physical and Chemical Properties of Dinoseb
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Parameter[a]	Value	Units	Source
Constituent: Dinoseb		na	
Water solubility	52	mg/L	Default EPA Region 6 value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Air diffusion coefficient	0.0215	cm^2/sec	SEVIEW chemical database
Henry's Law constant	4.56E-07	m^3-atm/mol	Default EPA Region 6 value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Molecular weight	240.24	g/mole	SEVIEW chemical database
Organic carbon adsorption coefficient (Koc)	3544	(ug/g)/(ug/mL)	Default EPA Region 6 value http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
Solid phase biodegradation rate	1.10E-03	1/day	based on site data
Liquid phase biodegradation rate	not included	1/day	na
Distribution coefficient (Kd)	7.08E-03	m^3/kg	Koc x organic carbon; assume 0.2% organic carbon
Water diffusion coefficient	2.38E-06	m^2/hr	SEVIEW chemical database

Notes:

a. For SESOIL modeling, remaining chemical properties set at zero.

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., Michalenko, E.M. 1991. Handbook of Environmental Degradation Rates. Lewis Publishers, Inc. Chelsea, MI.

TABLE B-2
Imput Parameters for Unsaturated Zone Soil Modeling with SESOIL
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Parameter	Value	Units	Source
Dry bulk density of soil	1.5	g/cm^3	Average dry density from June 1996 Ensafe FI Attachment A. Note: this is close to the average of reported values for Convent soil type of 1.48 g/cm^3 (Natural Resources Conservation Service, 2009. Physical Soil Properties - Phillips County, Arkansas. Web Soil Survey 2.2. National Cooperative Soil Survey.)
Effective porosity	0.30	--	Default value for water-filled soil porosity on EPA Region 6 SSL calculation page http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
Soil type(s)	CL and ML	na	clay, silt, and silty clay; Ensafe (1996) boring logs and physical property logs (pg 227 394 of Cedar FI Report.pdf); classified as Convent Silt Loam on the USDA Natural Resources Conservation Service soil map for Phillips County, Arkansas.
Unsaturated zone thickness	1370	cm	depth to top of alluvial aquifer based on log from well 4MW-4 (located just southeast of Site 3)
Intrinsic permeability	7.6e-10 (layers 1,2,3) 1e-11 (layer 4)	cm^2	layers 1, 2, 3: average of slug test values for MW-16 (8.2E-05 cm/sec) and EMW-6B (7E-05) presented in T5 of 2009 FI (AMEC Geomatrix, 2009); converted to intrinsic permeability; layer 4: assume hydraulic conductivity of 1e-6 cm/sec for semi-confining clay layer
Soil organic carbon	0.2	%	Default value on EPA Region 6 SSL calculation page http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
Soil disconnectedness index	10	na	from SEVIEW guidance based on soil type

Notes:

Ensafe (Environmental and Safety Designs, Inc.), 1996. *Field Investigation* [FI], *Cedar Chemical Corporation* . June.
AMEC Geomatrix, Inc., 2009. *Facility Investigation Report, Former Cedar Chemical Corporation, Helena-West Helena, Arkansas* . February.

TABLE B-3
Input Parameters for Contaminant Extent Modeling with SESOIL
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Parameter[a]	Value	Units	Source
Application area	9.3E+04	cm^2	planer (x-y) area of resiudal dinoseb concentrations in soil at Site 3 (model 10 by 10 ft sampled area)
Upper soil layer thickness	122	cm	ground surface to 4 ft below ground surface (bgs)
Second soil layer thickness	122	cm	4 to 8 ft bgs (contaminated zone)
Third soil layer thickness	1040	cm	contaminated zone to clay layer (8 ft bgs to 42 ft bgs)
Lower soil layer thickness	152	cm	clay layer (42 ft bgs to 47 ft bgs)
Contaminant concentration	52	mg/kg	average from 3/09 sampling in Site 3
Site latitude	N 34.52076	degrees	from TerraServer-usa.com based on the address/ approximate center of the Site
Spill index	1.0	na	assume one single contaminant application
Volatilization/Diffusion index (VOLF#)	0.00	na	little or no volatilization expected

Notes:
Climate data from SEVIEW database for Helena, AR

TABLE B-4
Input Parameters for Alluvial Aquifer Modeling with SESOIL
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Parameter	Value	Units	Source
Soil type(s)	SW, SP, GP	na	well-graded sand, poorly graded sand, and poorly graded gravel; FI (Ensafe 1996) boring logs and physical property logs (pg 227 - 394 of Cedar FI Report.pdf); pg 18 of 2009 FI gives the following: ~45-70 feet depth - fine grained sand with interbedded gravel; ~70 - 130 feet depth - fine to medium grained sand; and ~130 - 150 feet depth - medium to coarse sand with interbedded gravel.
Dry bulk density of soil	1380	kg/m^3	Middle of range recommended for sand by SEVIEW guidance (Version 6.3, January 2006, p. 98)
Effective porosity	0.30	--	Default value for water-filled soil porosity on EPA Region 6 SSL calculation page http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
Hydraulic conductivity	6.8E-01	m/hr	average value for the Alluvial Aquifer based on step drawdown tests (Table 5, FI, AMEC Geomatrix, February 2009)
Hydraulic gradient	1.3E-04 or 9.7E-04	m/m	1.3E-04 m/n calculated for the Site 3 area based on September 2008 Alluvial Aquifer Potentiometric Map (Fig 11, AMEC Geomatrix, Feb 2009); the calculated gradient in July 2008 is 9.7E-4 m/g (Fig 10, AMEC Geomatrix, Feb 2009).
Saturated thickness	30.80	m	Log for 4MW-4 (Ensafe, 1996) which is just SE of Site 3 and nearest deep boring to Site 3
Longitudinal dispersivity	6.3	m	Based on formula: Longitudinal dispersivity = $0.83\times([(\mathrm{Log}_{10}(L)]^{2.414})$ (units of feet), assumed plume length (L) calculated from plume map Figure 32 of FI Report (690 ft).
Horizontal transverse dispersivity	0.63	m	From relations in SEVIEW guidance (Version 6.3, January 2006, p. 134)
Vertical transverse dispersivity	0.63	m	From relations in SEVIEW guidance (Version 6.3, January 2006, p. 134)

Notes:

Ensafe (Environmental and Safety Designs, Inc.), 1996. *Field Investigation* [FI], *Cedar Chemical Corporation* . June.

AMEC Geomatrix, Inc., 2009. *Facility Investigation Report, Former Cedar Chemical Corporation, Helena-West Helena, Arkansas* . February.

Hydraulic gradients vary seasonally due to irrigation pumping and also result in variation in the distance to the site boundary;
189 m in July and 300 m in September.

TABLE B-5
Summary of SESOIL/AT123D Modeling Results for Dinoseb at Site 3
Former Cedar Chemical Facility
Helena-West Helena, Arkansas

Scenario	Model Input				Model Output	
	Soil Concentration[1] (mg/kg)	Contaminant Load[2] (ug/cm^2)	Degradation Rate[3] (1/day)	Distance X from Site 3[4] (m)	Simulated Maximum Groundwater Concentration at Distance X (mg/L)	Simulated Time to Reach Maximum at Distance X (years)
1	5.41E+07	9.90E+09	0.011	NA	7.09E-13	978
2	0.62	113	None	300 [5]	7.15E-03	337
3	5.4	988	None	189 [5]	7.06E-03	330
4	5.41E+07	9.90E+09	None	300 [5]	0	NA[7]
5	5.41E+07	9.90E+09	None	189 [5]	5.77E-03	954

Notes:

1. This is the soil concentration input into the 4-8 foot depth interval of the SESOIL model and represents the area of residual dinsoeb concentrations in subsurface soil at Site 3.
The maximum soil concentration that can be input into SESOIL is 5.4 g/g (5.4E+07 mg/kg). This input value is much greater than concentrations detected in March 2009 (range of 31.3 mg/kg to 81.4 mg/kg) or concentrations from the 1996 FI (range of 0.63 mg/kg to 13,000 mg.kg) and was used as a conservative input for scenarios 1, 4, and 5. Soil concentration values for scenarios 2 and 3 were calculated through an iterative approach and represent the modeled maximum soil concentrations which results in groundwater concentrations below the MCL directly beneath the source.
2. Concentration load (ug/cm2) = Conc x D x RS, where:
Conc = initial soil concentration in ug/gm
D = thickness of layer with constituent = 122 cm
RS = bulk soil density = 1.5 gm/cm^3
3. The degradation rate was calculated based on Site-specific data from Site 3.
4. For each scenario, the model is used to predict the maximum alluvial aquifer groundwater concentration at a distance, X, from the area of residual dinoseb concentrations at Site 3. This distance is 0 m for groundwater concentrations directly beneath Site 3 (Scenario 1), and 300 m or 189 m for modeled concentrations at the Facility Property boundary (Scenarios 2 through 5).
5. Potentiometric contour maps provided in the Facility Investigation Report (AMEC Geomatrix, 2009) indicate a seasonal effect on gradient and groundwater flow direction. These maps were used to calculated hydraulic gradients in the vicinity of the Site 3 area for July 2008 (0.00097 ft/ft) and September 2008 (0.00013 ft/ft). The resulting gradients and flow direction yield a distance to the Facility boundary of 189 meters for the 0.00097 ft/ft gradient and 300 meters for the 0.00013 ft/ft gradient).
6. The target groundwater concentrationwas the MCL for dinoseb, 0.007 mg/L.
7. For Scenario 4, the modeled concentration at the Facility Property boundary is 0 mg/L through the maximum simulation time of 999 years.

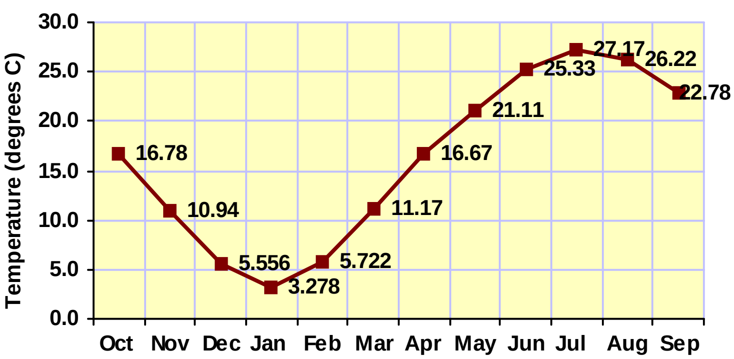
m - Meters
mg/kg - Milligrams per kilogram
mg/L - Milligrams per Liter

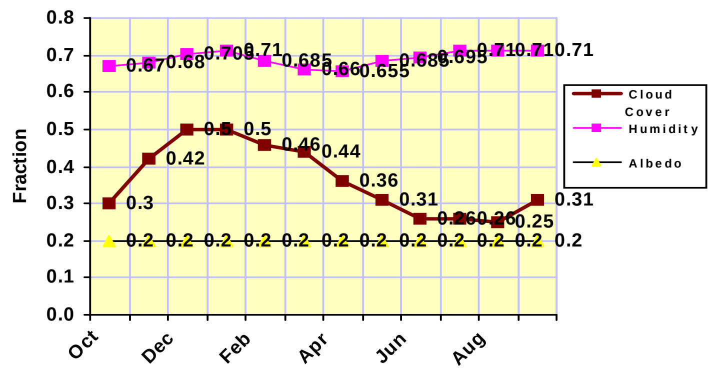
SESOIL Modeling Input - Climate Report

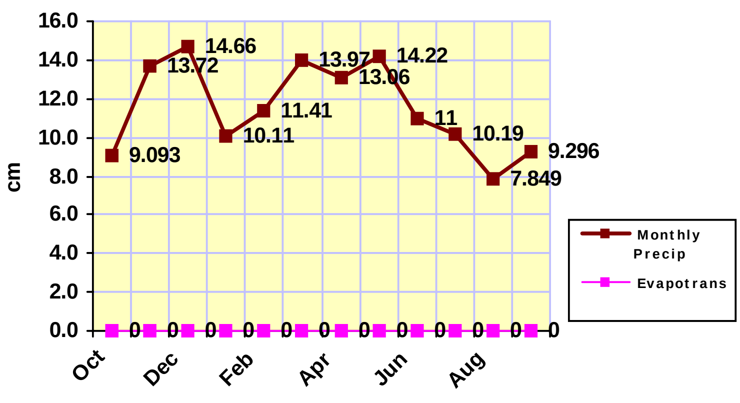
Climate Report

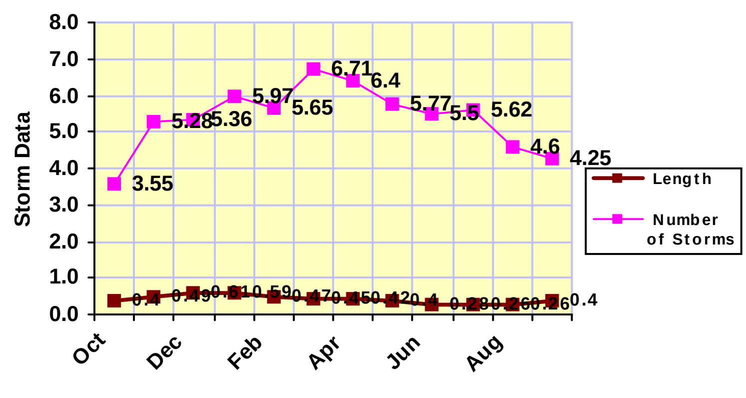
Location Description: HELENA
Climatic Input File: C:\SEVIEW63\HELENA.CLM

Month	Temperature		Precipitation		Evapotranspiration Rate		Storms		Cloud Cover	Albedo	Humidity
Units	^{o}C	^{o}F	cm	Inches	cm	Inches	# per Month	Length Days	Fraction	Fraction	Fraction
October	16.78	62.20	9.093	3.58	0.00	0.00	3.55	0.400	0.300	0.200	0.670
November	10.94	51.69	13.72	5.40	0.00	0.00	5.28	0.490	0.420	0.200	0.680
December	5.556	42.00	14.66	5.77	0.00	0.00	5.36	0.610	0.500	0.200	0.705
January	3.278	37.90	10.11	3.98	0.00	0.00	5.97	0.590	0.500	0.200	0.710
February	5.722	42.30	11.41	4.49	0.00	0.00	5.65	0.470	0.460	0.200	0.685
March	11.17	52.11	13.97	5.50	0.00	0.00	6.71	0.450	0.440	0.200	0.660
April	16.67	62.01	13.06	5.14	0.00	0.00	6.40	0.420	0.360	0.200	0.655
May	21.11	70.00	14.22	5.60	0.00	0.00	5.77	0.400	0.310	0.200	0.685
June	25.33	77.59	11.00	4.33	0.00	0.00	5.50	0.280	0.260	0.200	0.695
July	27.17	80.91	10.19	4.01	0.00	0.00	5.62	0.260	0.260	0.200	0.710
August	26.22	79.20	7.849	3.09	0.00	0.00	4.60	0.260	0.250	0.200	0.710
September	22.78	73.00	9.296	3.66	0.00	0.00	4.25	0.400	0.310	0.200	0.710
Total			138.58	54.56	0.00	0.00					







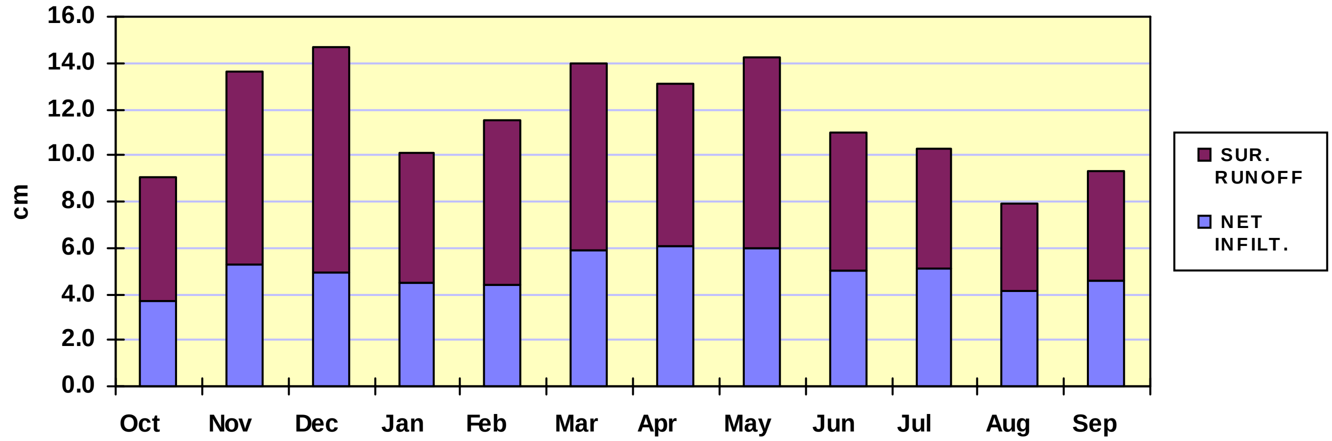


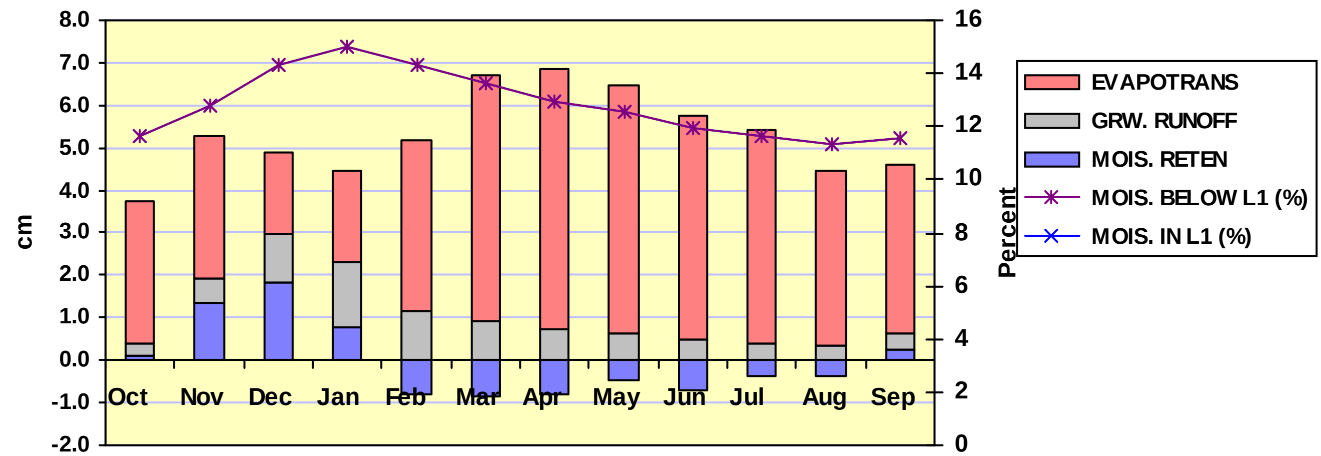
SESOIL Hydrologic Cycle Report

SESOIL Hydrologic Cycle Report

Scenario Description:

SESOIL Output File: C:\SEVIEW63\CEDAR4.OUT





	Surface Water Runoff		Net Infiltration		Evapotranspiration		Soil Moisture Retention		Groundwater Runoff (Recharge)		Soil Moisture	
											Layer 1	Below Layer 1
Units	cm	Inches	cm	Inches	cm	Inches	cm	Inches	cm	Inches	Percent	Percent
October	5.33	2.10	3.73	1.47	3.32	1.31	0.10	0.04	0.32	0.13	11.66	11.66
November	8.34	3.28	5.27	2.07	3.33	1.31	1.36	0.54	0.57	0.22	12.80	12.80
December	9.75	3.84	4.89	1.93	1.91	0.75	1.82	0.72	1.17	0.46	14.32	14.32
January	5.63	2.22	4.48	1.76	2.16	0.85	0.79	0.31	1.53	0.60	14.98	14.98
February	7.08	2.79	4.41	1.74	4.02	1.58	-0.79	-0.31	1.18	0.46	14.32	14.32
March	8.12	3.20	5.87	2.31	5.80	2.28	-0.86	-0.34	0.93	0.37	13.60	13.60
April	7.08	2.79	6.04	2.38	6.10	2.40	-0.79	-0.31	0.73	0.29	12.94	12.94
May	8.30	3.27	5.97	2.35	5.81	2.29	-0.48	-0.19	0.64	0.25	12.54	12.54
June	5.97	2.35	5.04	1.98	5.25	2.07	-0.69	-0.27	0.48	0.19	11.96	11.96
July	5.20	2.05	5.06	1.99	5.01	1.97	-0.36	-0.14	0.41	0.16	11.66	11.66
August	3.81	1.50	4.11	1.62	4.15	1.63	-0.36	-0.14	0.32	0.13	11.36	11.36
September	4.72	1.86	4.59	1.81	3.98	1.57	0.26	0.10	0.35	0.14	11.58	11.58
Total	79.32	31.23	59.45	23.41	50.84	20.01	0.00	0.00	8.62	3.39		

SESOIL Model Results – CEDAR04

SESOIL Profile and Load Report

Layer No.	Number of Sub-Layers	Thickness		Intrinsic Permeability	Organic Carbon Content	Adsorption Coefficient	Cation Exchange Capacity	Freundlich Exponent	Solid Phase Degradation Rate	Liquid Phase Degradation Rate	Soil pH
		cm	feet	cm^2	percent	µg/g / µg/mL	mEq / 100 g soil	unitless	1/day	1/day	pH
1	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	1.10E-03	0.00E+00	7.00
2	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	1.10E-03	0.00E+00	7.00
3	10	1040.0	34.12	7.60E-10	0.20	0.00	0.00	1.00	1.10E-03	0.00E+00	7.00
4	10	152.0	4.99	1.00E-11	0.20	0.00	0.00	1.00	1.10E-03	0.00E+00	7.00

Soil Parameters

Bulk Density (g/cm^3)	1.50
Effective Porosity (fraction)	0.30
Soil Pore Disconnectedness	10.00

Application Parameters

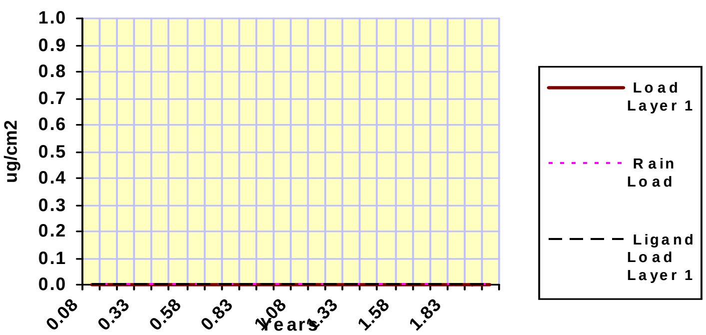
Area	cm^2	9.30E+4
	ft^2	100.10
Latitude	degrees	34.5
Spill Index		1

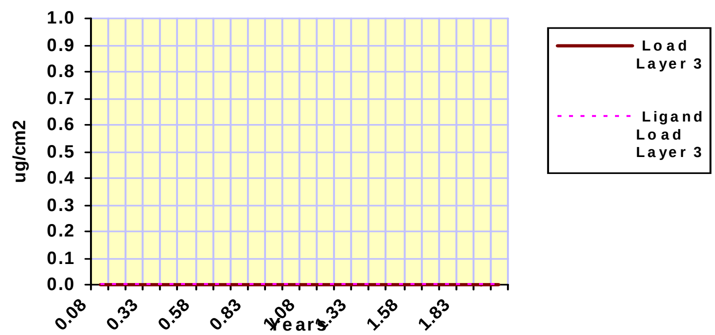
Chemical Parameters

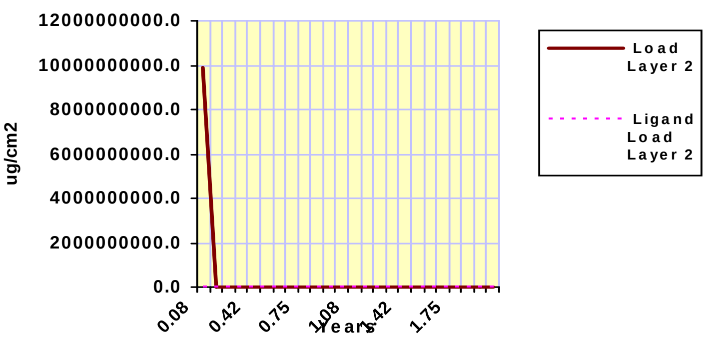
Water Solubility (µg/mL)	52.0	**Moles Ligand / Moles Chemical**	0.00
Henry's Law (M^3atm/mol)	4.56E-7	**Ligand Molecular Weight** (g/mol)	0.00
K_{oc} (µg/g)/(µg/mL)	3540.00	**Base Hydrolysis Rate** (L/mol/day)	0.00
Valance (g/mole)	0.00	**Ligand Dissociation Constant**	0.00
Air Diffusion Coefficient (cm^2/sec)	2.15E-2	**Neutral Hydrolysis Rate** (L/mol/day)	0.00
Water Diffusion Coefficient (cm^2/sec)	6.62E-6	**Acid Hydrolysis Rate** (L/mol/day)	0.00
Molecular Weight (g/mol)	240.00		

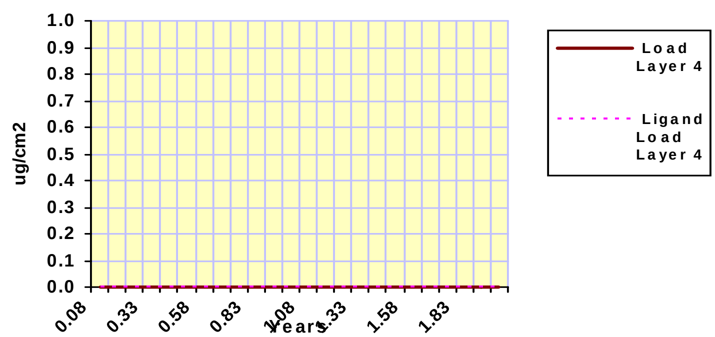
Output File: site biodeg
C:\SEVIEW63\CEDAR04.OUT
Chemical File: Dinoseb - Region 6 and site soil degradation
C:\SEVIEW63\DINOSEBG.CHM
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR1.APL

Sublayer Loads	1	2	3	4	5	6	7	8	9	10
Layer 1 (ug/g)										
Layer 2 (ug/g)										
Layer 3 (ug/g)										
Layer 4 (ug/g)										









SESOIL Pollutant Cycle Report

Scenario Description: site biodeg

SESOIL Output File: C:\SEVIEW63\CEDAR04.OUT

SESOIL Process	Pollutant Mass (µg)	Percent of Total
Volatilized	4.366E-06	0.00
In Soil Air	8.076E+02	0.00
Sur. Runoff	0.000E+00	0.00
In Washld	0.000E+00	0.00
Ads On Soil	4.424E+09	0.00
Hydrol Soil	0.000E+00	0.00
Degrad Soil	1.745E+12	0.19
Pure Phase	9.207E+14	100.00
Complexed	0.000E+00	0.00
Immobile CEC	0.000E+00	0.00
Hydrol CEC	0.000E+00	0.00
In Soil Moi	8.140E+07	0.00
Hydrol Mois	0.000E+00	0.00
Degrad Mois	0.000E+00	0.00
Other Trans	0.000E+00	0.00
Other Sinks	0.000E+00	0.00
Gwr. Runoff	4.283E-03	0.00
Total Output	9.224E+14	100.19
Total Input	9.207E+14	
Input - Output	-1.749E+12	

Maximum leachate concentration: 1.001E-11 **mg/l**

Climate File: HELENA
C:\SEVIEW63\HELENA.CLM

Chemical File: Dinoseb - Region 6 and site soil degradation
C:\SEVIEW63\DINOSEBG.CHM

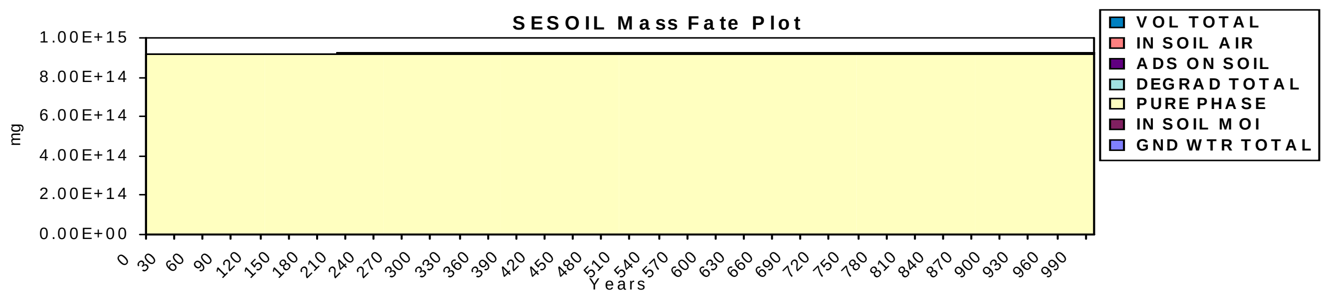
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI

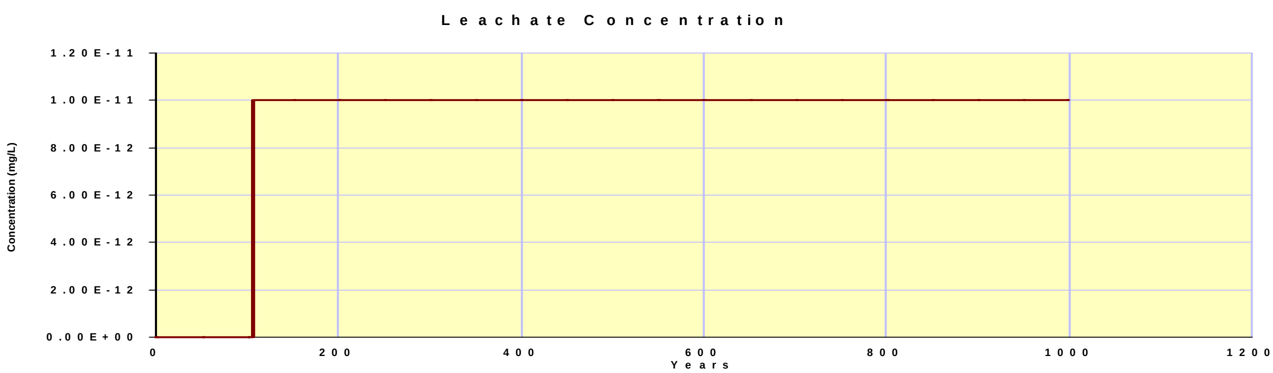
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR1.APL

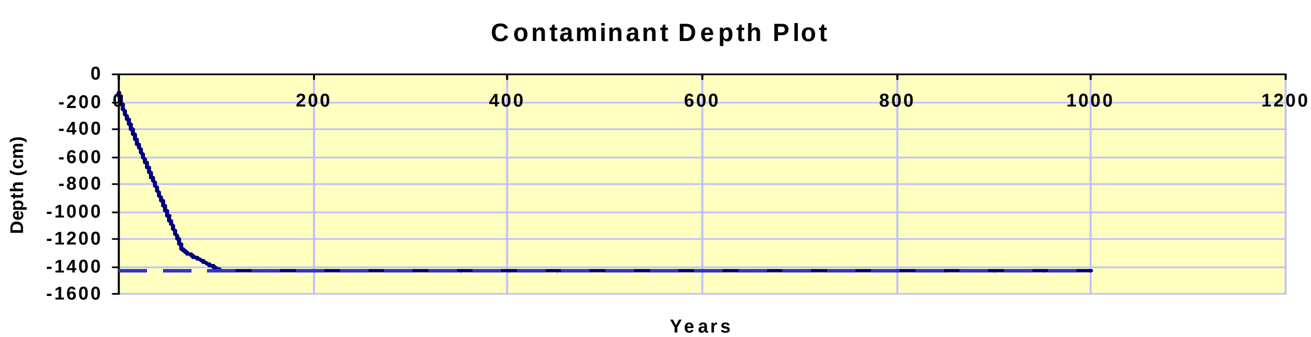
Starting Depth: 129.70 **cm**

Ending Depth: 1436.00 **cm**

Total Depth: 1436.00 **cm**

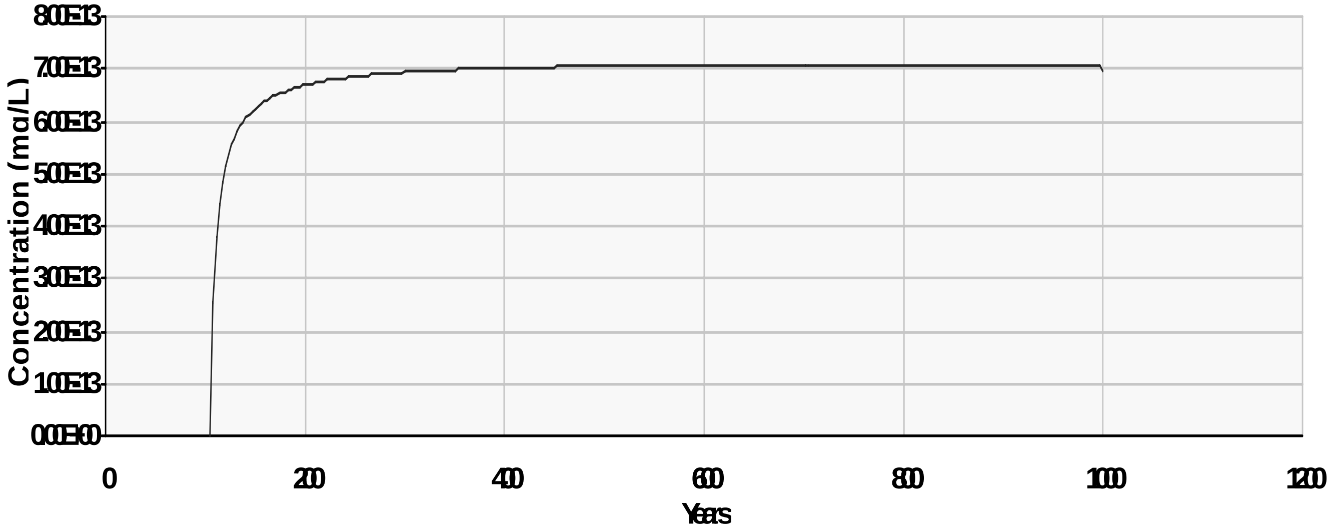






AT123D Point of Compliance Report

site biodeg
site biodeg



Maximum Concentration: 7.090E-13 mg/L
Year of Maximum Concentration: 978.0000

Output Coordinates

X:	0.00000 m	0.0000 ft	**Output Time Step:**	0.2500 years	3.0016 months
Y:	0.00000 m	0.0000 ft	**Initial Load (mg/kg):**	0.0000E+00	
Z:	0.00000 m	0.0000 ft	**Initial Load (kg):**	0.7300E+03	

Input Parameters

Porosity:	0.30000	**Soil Organic Carbon Content (percent):**		0.00000
Hydraulic Gradient:	0.00013	**Carbon Adsorption Coeff. (ug/g)/(ug/ml):**		0.0000E+00

Hydraulic Conductivity:	6.800E-01	m/hr	1.888E-02	cm/sec
Soil Bulk Density:	1.380E+03	kg/m3	1.380E+00	g/cm3
Aquifer Width:	Infinite	m	Infinite	ft
Aquifer Depth:	3.080E+01	m	1.010E+02	ft
Kd:	7.080E-03	m3/kg	7.080E+00	(ug/g)(ug/ml)
Molecular Diffusion:	2.383E-06	m2/hr	6.619E-06	cm2/sec
Decay Coefficient:	0.000E+00	1/hr	0.000E+00	1/day

Retardation Factor:	3.357E+01			
Retarded Darcy Velocity:	8.778E-06	m2/hr	2.438E-05	cm2/sec
Retarded Longitudinal Disp. Coefficient:	5.554E-05	m2/hr	1.542E-04	cm2/sec
Retarded Lateral Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec
Retarded Vertical Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec

Dispersivities	Meters	Feet
Longitudinal:	6.300E+00	2.066E+01
Lateral:	6.300E-01	2.066E+00
Vertical:	6.300E-01	2.066E+00

Load	Begin (m)	End (m)	Begin (ft)	End (ft)
X:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Y:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Z:	0.000E+00	0.000E+00	0.000E+00	0.000E+00

C:\SEVIEW63\CEDAR04.ATI
C:\SEVIEW63\CEDAR04.ATO

SESOIL Model Results – CEDAR06

SESOIL Profile and Load Report

Layer No.	Number of Sub-Layers	Thickness		Intrinsic Permeability	Organic Carbon Content	Adsorption Coefficient	Cation Exchange Capacity	Freundlich Exponent	Solid Phase Degradation Rate	Liquid Phase Degradation Rate	Soil pH
		cm	feet	cm^2	percent	µg/g / µg/mL	mEq / 100 g soil	unitless	1/day	1/day	pH
1	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
2	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
3	10	1040.0	34.12	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
4	10	152.0	4.99	1.00E-11	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00

Soil Parameters

Bulk Density (g/cm^3)	1.50
Effective Porosity (fraction)	0.30
Soil Pore Disconnectedness	10.00

Application Parameters

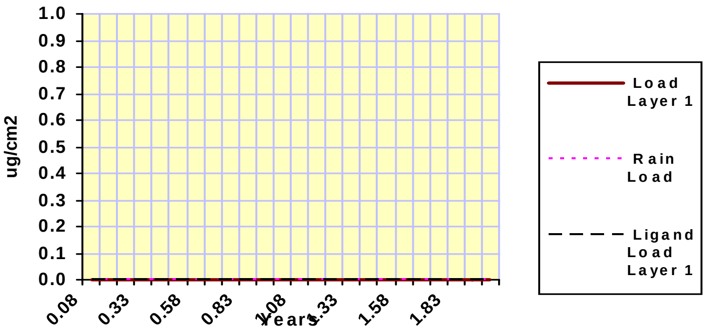
Area cm^2	9.30E+4
ft^2	100.10
Latitude degrees	34.5
Spill Index	1

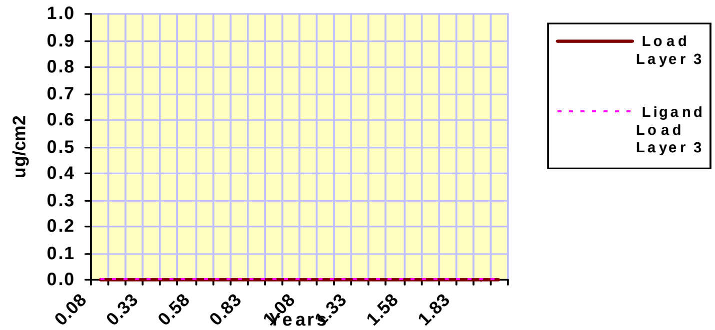
Chemical Parameters

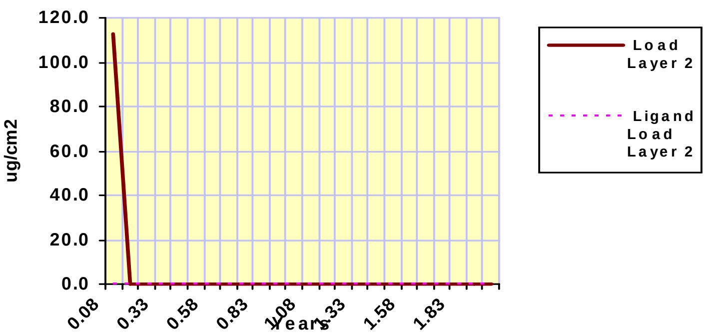
Water Solubility (µg/mL)	52.0	**Moles Ligand / Moles Chemical**	0.00
Henry's Law (M^3atm/mol)	4.56E-7	**Ligand Molecular Weight** (g/mol)	0.00
K_{oc} (µg/g)/(µg/mL)	3540.00	**Base Hydrolysis Rate** (L/mol/day)	0.00
Valance (g/mole)	0.00	**Ligand Dissociation Constant**	0.00
Air Diffusion Coefficient (cm^2/sec)	2.15E-2	**Neutral Hydrolysis Rate** (L/mol/day)	0.00
Water Diffusion Coefficient (cm^2/sec)	6.62E-6	**Acid Hydrolysis Rate** (L/mol/day)	0.00
Molecular Weight (g/mol)	240.00		

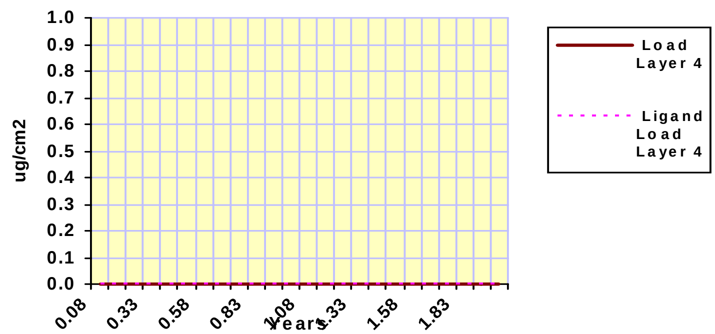
Output File: no biodeg
C:\SEVIEW63\CEDAR06.OUT
Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR2.APL

Sublayer Loads	1	2	3	4	5	6	7	8	9	10
Layer 1 (ug/g)										
Layer 2 (ug/g)										
Layer 3 (ug/g)										
Layer 4 (ug/g)										









SESOIL Pollutant Cycle Report

Scenario Description: no biodeg

SESOIL Output File: C:\SEVIEW63\CEDAR06.OUT

SESOIL Process	Pollutant Mass (µg)	Percent of Total
Volatilized	1.745E-06	0.00
In Soil Air	4.674E-01	0.00
Sur. Runoff	0.000E+00	0.00
In Washld	0.000E+00	0.00
Ads On Soil	2.560E+06	24.36
Hydrol Soil	0.000E+00	0.00
Degrad Soil	0.000E+00	0.00
Pure Phase	0.000E+00	0.00
Complexed	0.000E+00	0.00
Immobile CEC	0.000E+00	0.00
Hydrol CEC	0.000E+00	0.00
In Soil Moi	4.711E+04	0.45
Hydrol Mois	0.000E+00	0.00
Degrad Mois	0.000E+00	0.00
Other Trans	0.000E+00	0.00
Other Sinks	0.000E+00	0.00
Gwr. Runoff	7.621E+06	72.51
Total Output	1.022E+07	97.33
Total Input	1.051E+07	
Input - Output	2.810E+05	

Maximum leachate concentration: 1.060E-01 **mg/l**

Climate File: HELENA
C:\SEVIEW63\HELENA.CLM

Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM

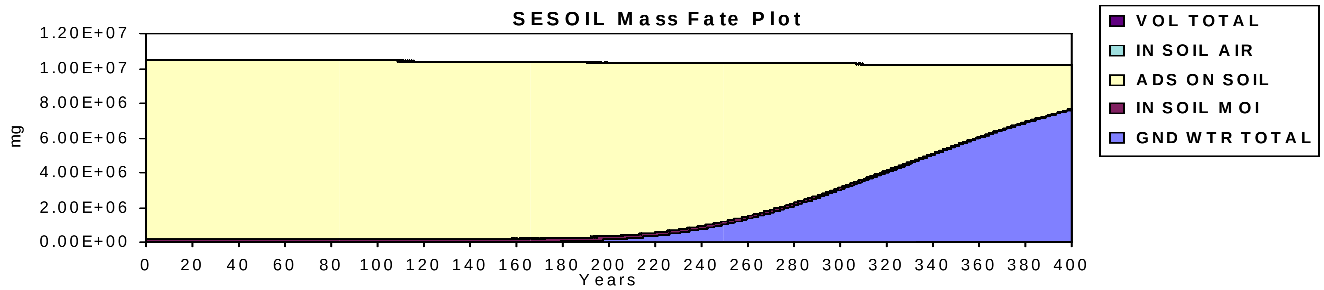
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI

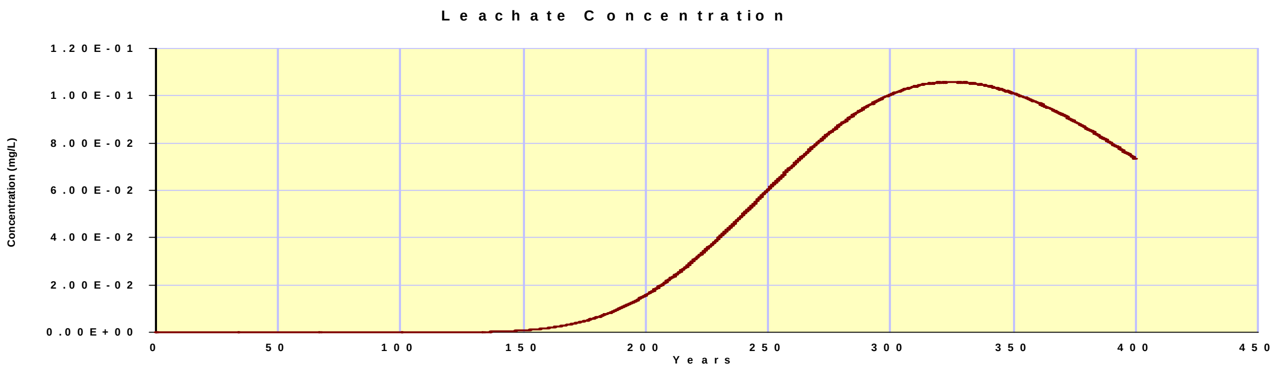
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR2.APL

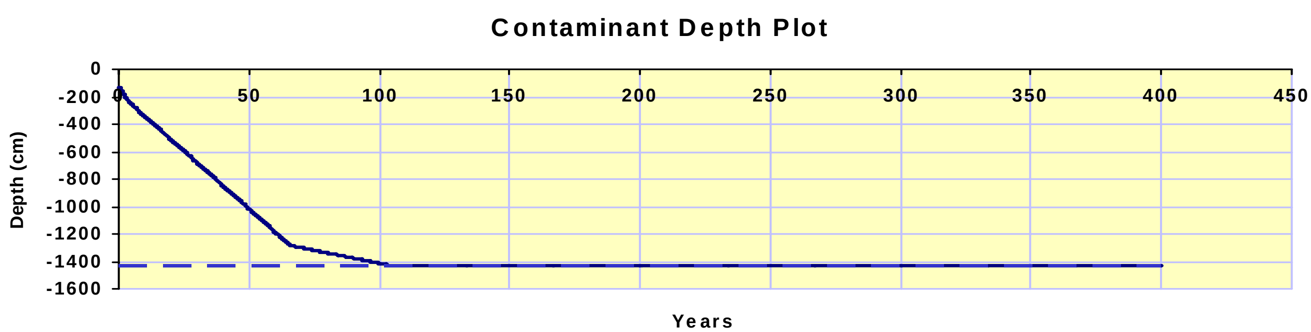
Starting Depth: 129.70 **cm**

Ending Depth: 1436.00 **cm**

Total Depth: 1436.00 **cm**

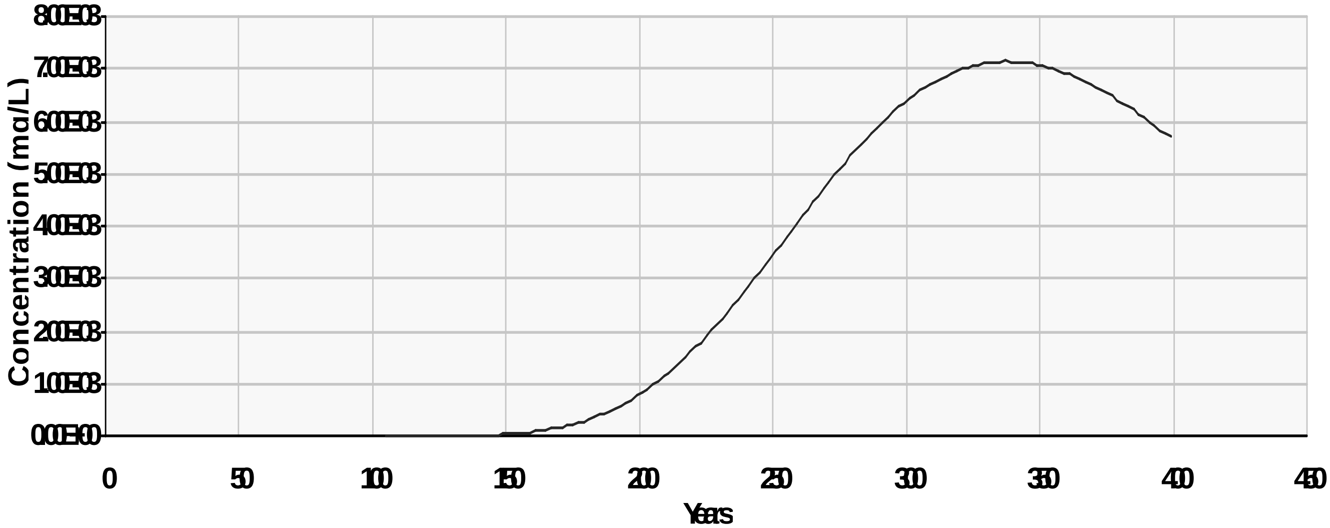






AT123D Point of Compliance Report

no biodeg
no biodeg



Maximum Concentration: 7.150E-03 mg/L
Year of Maximum Concentration: 337.0000

Output Coordinates

X:	0.00000 m	0.0000 ft	**Output Time Step:**	0.1667 years	2.0011 months
Y:	0.00000 m	0.0000 ft	**Initial Load (mg/kg):**	0.0000E+00	
Z:	0.00000 m	0.0000 ft	**Initial Load (kg):**	0.7300E+03	

Input Parameters

Porosity:	0.30000	**Soil Organic Carbon Content (percent):**	0.00000
Hydraulic Gradient:	0.00013	**Carbon Adsorption Coeff. (ug/g)/(ug/ml):**	0.0000E+00

Hydraulic Conductivity:	6.800E-01	m/hr	1.888E-02	cm/sec
Soil Bulk Density:	1.380E+03	kg/m3	1.380E+00	g/cm3
Aquifer Width:	Infinite	m	Infinite	ft
Aquifer Depth:	3.080E+01	m	1.010E+02	ft
Kd:	7.080E-03	m3/kg	7.080E+00	(ug/g)(ug/ml)
Molecular Diffusion:	2.383E-06	m2/hr	6.619E-06	cm2/sec
Decay Coefficient:	0.000E+00	1/hr	0.000E+00	1/day

Retardation Factor:	3.357E+01			
Retarded Darcy Velocity:	8.778E-06	m2/hr	2.438E-05	cm2/sec
Retarded Longitudinal Disp. Coefficient:	5.554E-05	m2/hr	1.542E-04	cm2/sec
Retarded Lateral Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec
Retarded Vertical Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec

Dispersivities	Meters	Feet
Longitudinal:	6.300E+00	2.066E+01
Lateral:	6.300E-01	2.066E+00
Vertical:	6.300E-01	2.066E+00

Load	Begin (m)	End (m)	Begin (ft)	End (ft)
X:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Y:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Z:	0.000E+00	0.000E+00	0.000E+00	0.000E+00

C:\SEVIEW63\CEDAR06.ATI
C:\SEVIEW63\CEDAR06.ATO

SESOIL Model Results – CEDAR12

SESOIL Profile and Load Report

Layer No.	Number of Sub-Layers	Thickness		Intrinsic Permeability	Organic Carbon Content	Adsorption Coefficient	Cation Exchange Capacity	Freundlich Exponent	Solid Phase Degradation Rate	Liquid Phase Degradation Rate	Soil pH
		cm	feet	cm^2	percent	µg/g / µg/mL	mEq / 100 g soil	unitless	1/day	1/day	pH
1	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
2	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
3	10	1040.0	34.12	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
4	10	152.0	4.99	1.00E-11	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00

Soil Parameters

Bulk Density (g/cm^3)	1.50
Effective Porosity (fraction)	0.30
Soil Pore Disconnectedness	10.00

Application Parameters

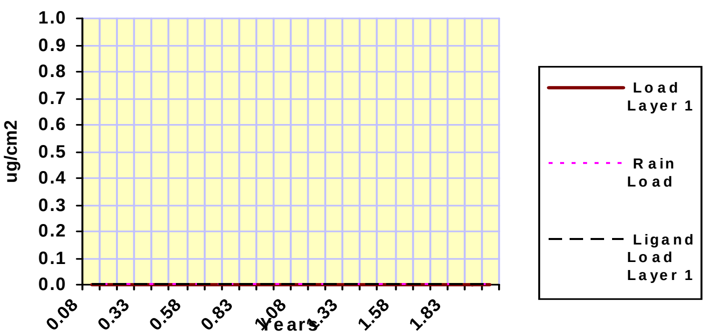
Area cm^2	9.30E+4
ft^2	100.10
Latitude degrees	34.5
Spill Index	1

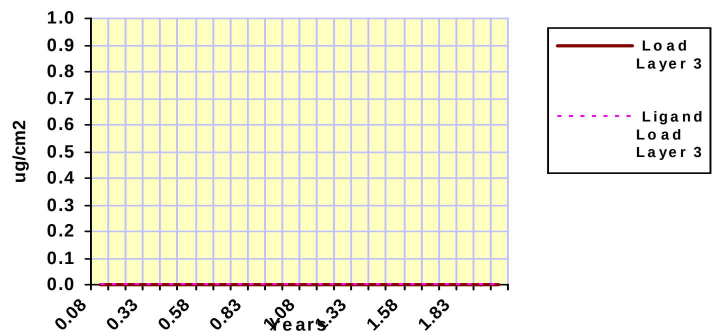
Chemical Parameters

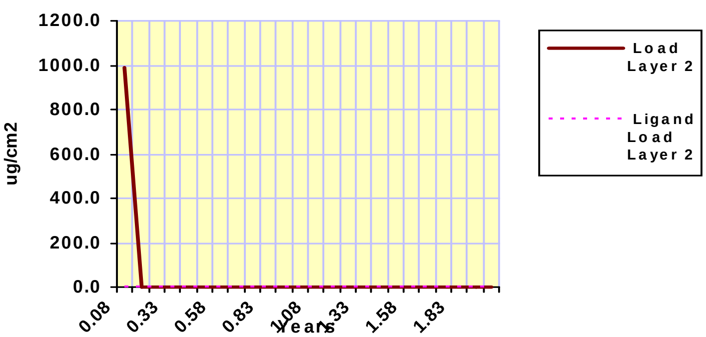
Water Solubility (µg/mL)	52.0	**Moles Ligand / Moles Chemical**	0.00
Henry's Law (M^3atm/mol)	4.56E-7	**Ligand Molecular Weight** (g/mol)	0.00
K_{oc} (µg/g)/(µg/mL)	3540.00	**Base Hydrolysis Rate** (L/mol/day)	0.00
Valance (g/mole)	0.00	**Ligand Dissociation Constant**	0.00
Air Diffusion Coefficient (cm^2/sec)	2.15E-2	**Neutral Hydrolysis Rate** (L/mol/day)	0.00
Water Diffusion Coefficient (cm^2/sec)	6.62E-6	**Acid Hydrolysis Rate** (L/mol/day)	0.00
Molecular Weight (g/mol)	240.00		

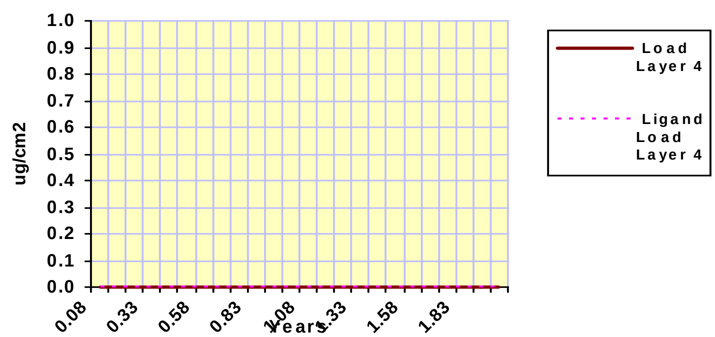
Output File: no biodeg
C:\SEVIEW63\CEDAR12.OUT
Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR1.APL

Sublayer Loads	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Layer 1 (ug/g)										
Layer 2 (ug/g)										
Layer 3 (ug/g)										
Layer 4 (ug/g)										









SESOIL Pollutant Cycle Report

Scenario Description: no biodeg

SESOIL Output File: C:\SEVIEW63\CEDAR12.OUT

SESOIL Process	Pollutant Mass (µg)	Percent of Total
Volatilized	4.366E-06	0.00
In Soil Air	1.284E-04	0.00
Sur. Runoff	0.000E+00	0.00
In Washld	0.000E+00	0.00
Ads On Soil	7.038E+02	0.00
Hydrol Soil	0.000E+00	0.00
Degrad Soil	0.000E+00	0.00
Pure Phase	0.000E+00	0.00
Complexed	0.000E+00	0.00
Immobile CEC	0.000E+00	0.00
Hydrol CEC	0.000E+00	0.00
In Soil Moi	1.295E+01	0.00
Hydrol Mois	0.000E+00	0.00
Degrad Mois	0.000E+00	0.00
Other Trans	0.000E+00	0.00
Other Sinks	0.000E+00	0.00
Gwr. Runoff	8.978E+07	97.72
Total Output	8.978E+07	97.72
Total Input	9.188E+07	
Input - Output	2.097E+06	

Maximum leachate concentration: 9.355E-01 **mg/l**

Climate File: HELENA
C:\SEVIEW63\HELENA.CLM

Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM

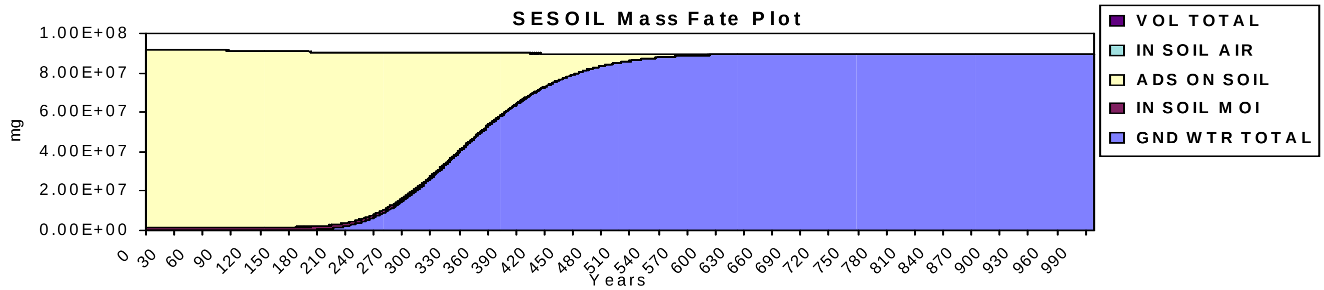
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI

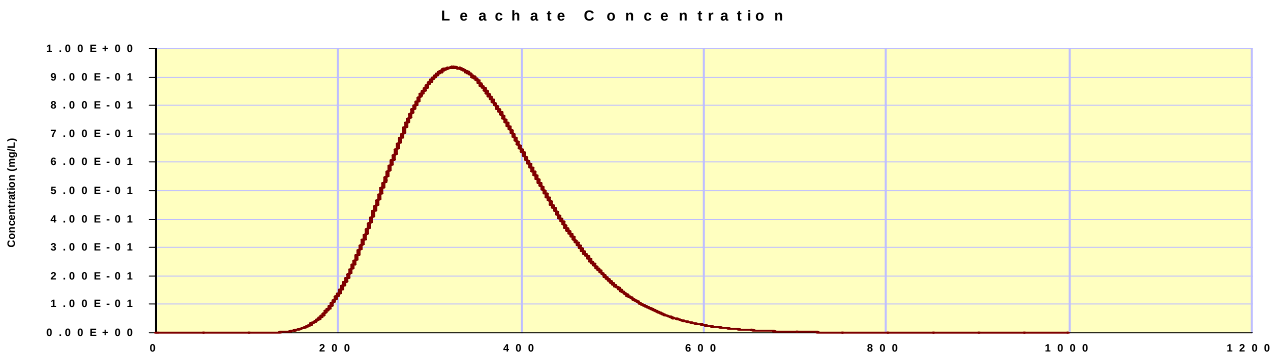
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR1.APL

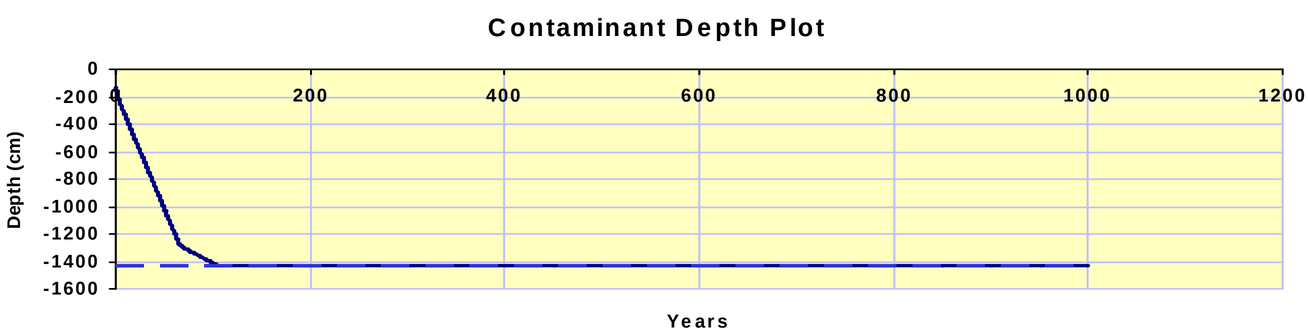
Starting Depth: 129.70 **cm**

Ending Depth: 1436.00 **cm**

Total Depth: 1436.00 **cm**

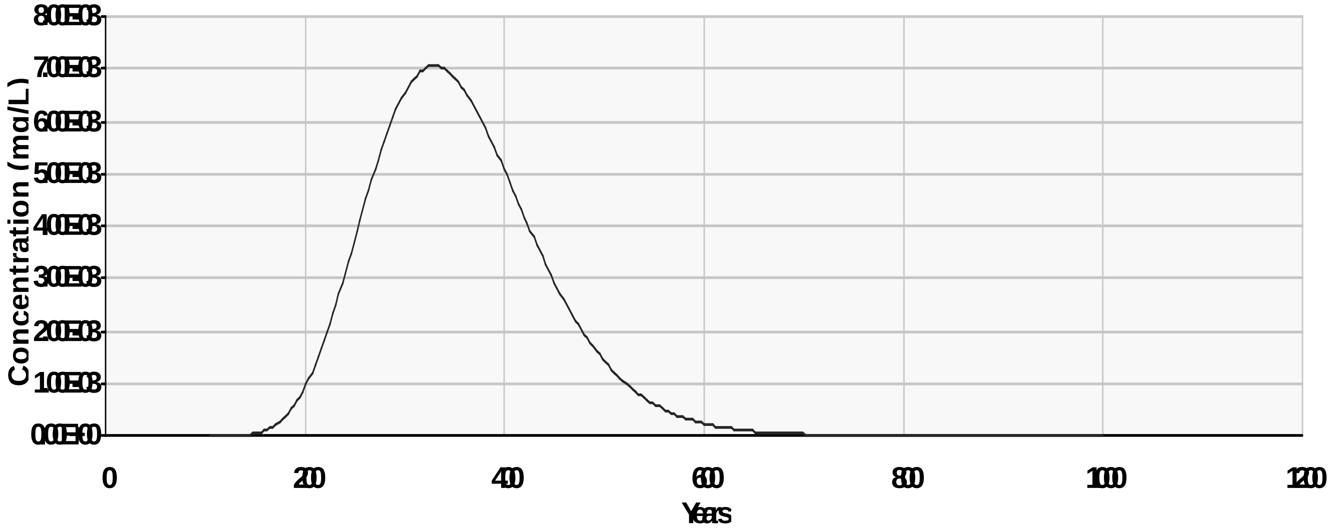






AT123D Point of Compliance Report

no biodeg
no biodeg



Maximum Concentration: 7.060E-03 mg/L
Year of Maximum Concentration: 330.0000

Output Coordinates

X:	0.00000 m	0.0000 ft	**Output Time Step:**	0.2500 years	3.0016 months
Y:	0.00000 m	0.0000 ft	**Initial Load (mg/kg):**	0.0000E+00	
Z:	0.00000 m	0.0000 ft	**Initial Load (kg):**	0.7300E+03	

Input Parameters

Porosity:	0.30000	
Hydraulic Gradient:	0.00097	
Soil Organic Carbon Content (percent):	0.00000	
Carbon Adsorption Coeff. (ug/g)/(ug/ml):	0.0000E+00	

Hydraulic Conductivity:	6.800E-01	m/hr	1.888E-02	cm/sec
Soil Bulk Density:	1.380E+03	kg/m3	1.380E+00	g/cm3
Aquifer Width:	Infinite	m	Infinite	ft
Aquifer Depth:	3.080E+01	m	1.010E+02	ft
Kd:	7.080E-03	m3/kg	7.080E+00	(ug/g)(ug/ml)
Molecular Diffusion:	2.383E-06	m2/hr	6.619E-06	cm2/sec
Decay Coefficient:	0.000E+00	1/hr	0.000E+00	1/day

Retardation Factor:	3.357E+01			
Retarded Darcy Velocity:	6.550E-05	m2/hr	1.819E-04	cm2/sec
Retarded Longitudinal Disp. Coefficient:	4.129E-04	m2/hr	1.146E-03	cm2/sec
Retarded Lateral Dispersion Coefficient:	4.150E-05	m2/hr	1.152E-04	cm2/sec
Retarded Vertical Dispersion Coefficient:	4.150E-05	m2/hr	1.152E-04	cm2/sec

Dispersivities	**Meters**	**Feet**
Longitudinal:	6.300E+00	2.066E+01
Lateral:	6.300E-01	2.066E+00
Vertical:	6.300E-01	2.066E+00

Load	Begin (m)	End (m)	Begin (ft)	End (ft)
X:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Y:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Z:	0.000E+00	0.000E+00	0.000E+00	0.000E+00

C:\SEVIEW63\CEDAR12.ATI
C:\SEVIEW63\CEDAR12.ATO

SESOIL Model Results – CEDAR 14

SESOIL Profile and Load Report

Layer No.	Number of Sub-Layers	Thickness		Intrinsic Permeability	Organic Carbon Content	Adsorption Coefficient	Cation Exchange Capacity	Freundlich Exponent	Solid Phase Degradation Rate	Liquid Phase Degradation Rate	Soil pH
		cm	feet	cm^2	percent	µg/g / µg/mL	mEq / 100 g soil	unitless	1/day	1/day	pH
1	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
2	10	122.0	4.00	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
3	10	1040.0	34.12	7.60E-10	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00
4	10	152.0	4.99	1.00E-11	0.20	0.00	0.00	1.00	0.00E+00	0.00E+00	7.00

Soil Parameters

Bulk Density (g/cm^3)	1.50
Effective Porosity (fraction)	0.30
Soil Pore Disconnectedness	10.00

Application Parameters

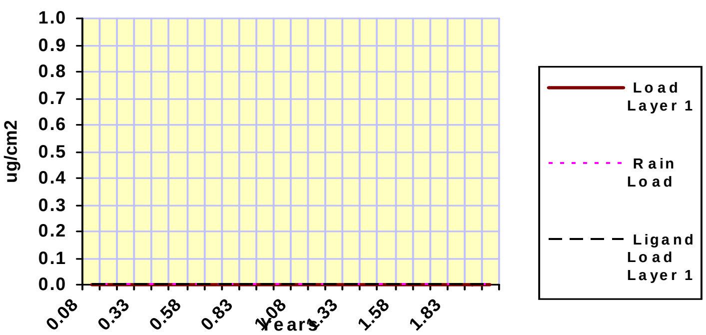
Area cm^2	9.30E+4
ft^2	100.10
Latitude degrees	34.5
Spill Index	1

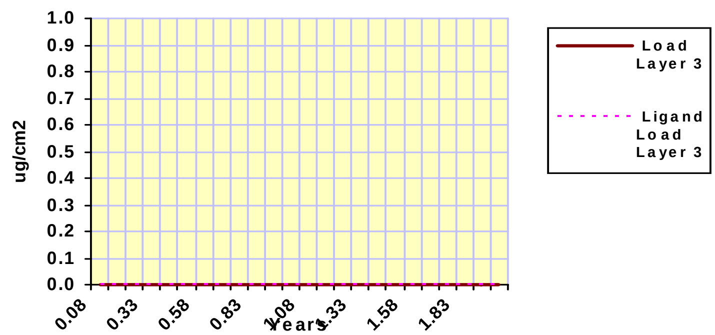
Chemical Parameters

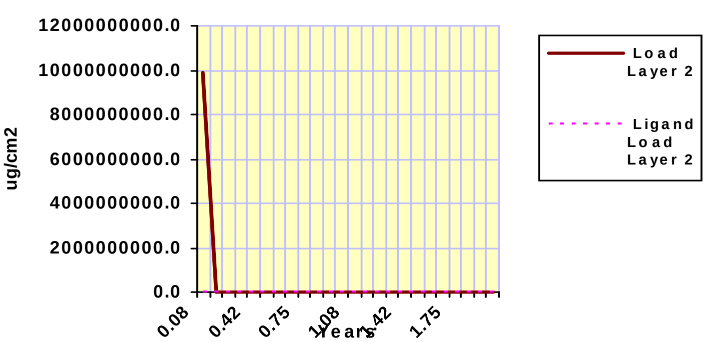
Water Solubility (µg/mL)	52.0	**Moles Ligand / Moles Chemical**	0.00
Henry's Law (M^3atm/mol)	4.56E-7	**Ligand Molecular Weight** (g/mol)	0.00
K_{oc} (µg/g)/(µg/mL)	3540.00	**Base Hydrolysis Rate** (L/mol/day)	0.00
Valance (g/mole)	0.00	**Ligand Dissociation Constant**	0.00
Air Diffusion Coefficient (cm^2/sec)	2.15E-2	**Neutral Hydrolysis Rate** (L/mol/day)	0.00
Water Diffusion Coefficient (cm^2/sec)	6.62E-6	**Acid Hydrolysis Rate** (L/mol/day)	0.00
Molecular Weight (g/mol)	240.00		

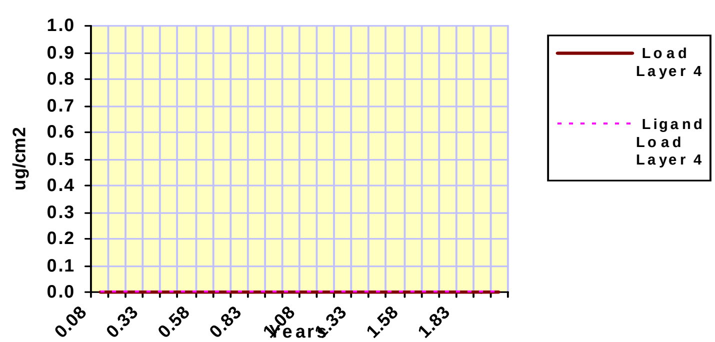
Output File: no biodeg
C:\SEVIEW63\CEDAR14.OUT
Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR2.APL

Sublayer Loads	1	2	3	4	5	6	7	8	9	10
Layer 1 (ug/g)										
Layer 2 (ug/g)										
Layer 3 (ug/g)										
Layer 4 (ug/g)										









SESOIL Pollutant Cycle Report

Scenario Description: no biodeg

SESOIL Output File: C:\SEVIEW63\CEDAR14.OUT

SESOIL Process	Pollutant Mass (µg)	Percent of Total
Volatilized	4.366E-06	0.00
In Soil Air	1.233E+04	0.00
Sur. Runoff	0.000E+00	0.00
In Washld	0.000E+00	0.00
Ads On Soil	6.755E+10	0.01
Hydrol Soil	0.000E+00	0.00
Degrad Soil	0.000E+00	0.00
Pure Phase	9.221E+14	100.15
Complexed	0.000E+00	0.00
Immobile CEC	0.000E+00	0.00
Hydrol CEC	0.000E+00	0.00
In Soil Moi	1.243E+09	0.00
Hydrol Mois	0.000E+00	0.00
Degrad Mois	0.000E+00	0.00
Other Trans	0.000E+00	0.00
Other Sinks	0.000E+00	0.00
Gwr. Runoff	1.851E+10	0.00
Total Output	9.222E+14	100.16
Total Input	9.207E+14	
Input - Output	-1.504E+12	

Maximum leachate concentration: 5.207E+01 **mg/l**

Climate File: HELENA
C:\SEVIEW63\HELENA.CLM

Chemical File: Dinoseb - low Koc used for Cedar Chemical site
C:\SEVIEW63\DINOSEB.CHM

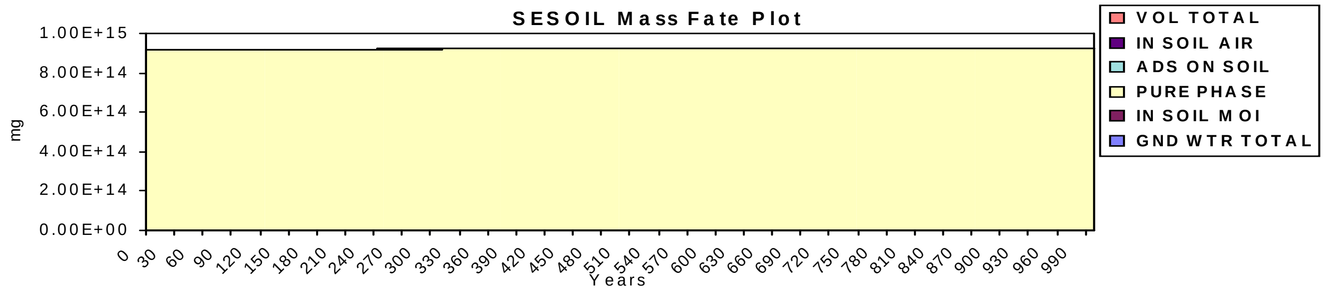
Soil File: Cedar chemical soil
C:\SEVIEW63\CEDARCHM.SOI

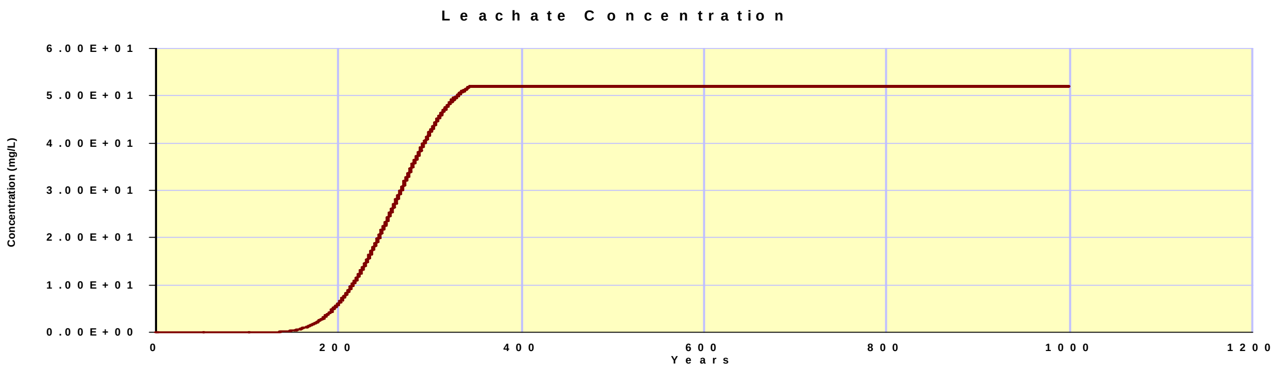
Application File: Cedar Chemical
C:\SEVIEW63\CEDAR2.APL

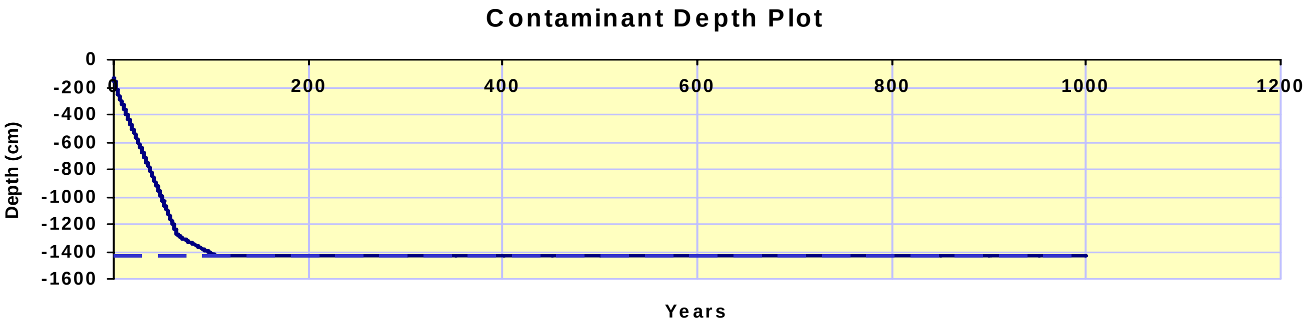
Starting Depth: 129.70 **cm**

Ending Depth: 1436.00 **cm**

Total Depth: 1436.00 **cm**







AT123D Point of Compliance Report

no biodeg
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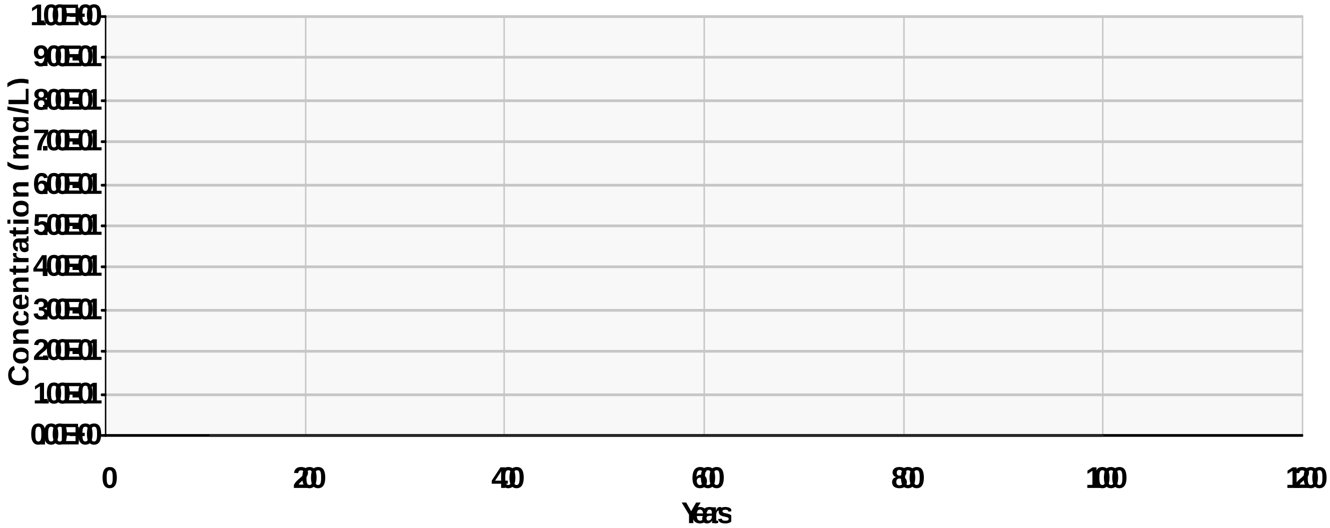

Maximum Concentration: 0.000E+00 mg/L
Year of Maximum Concentration: 999.00

Output Coordinates

X:	300.00000 m	984.2400 ft	**Output Time Step:**	0.2500 years	3.0016 months
Y:	0.00000 m	0.0000 ft	**Initial Load (mg/kg):**	0.0000E+00	
Z:	0.00000 m	0.0000 ft	**Initial Load (kg):**	0.7300E+03	

Input Parameters

Porosity:	0.30000	**Soil Organic Carbon Content (percent):**		0.00000
Hydraulic Gradient:	0.00013	**Carbon Adsorption Coeff. (ug/g)/(ug/ml):**		0.0000E+00

Hydraulic Conductivity:	6.800E-01	m/hr	1.888E-02	cm/sec
Soil Bulk Density:	1.380E+03	kg/m3	1.380E+00	g/cm3
Aquifer Width:	Infinite	m	Infinite	ft
Aquifer Depth:	3.080E+01	m	1.010E+02	ft
Kd:	7.080E-03	m3/kg	7.080E+00	(ug/g)(ug/ml)
Molecular Diffusion:	2.383E-06	m2/hr	6.619E-06	cm2/sec
Decay Coefficient:	0.000E+00	1/hr	0.000E+00	1/day

Retardation Factor:	3.357E+01			
Retarded Darcy Velocity:	8.778E-06	m2/hr	2.438E-05	cm2/sec
Retarded Longitudinal Disp. Coefficient:	5.554E-05	m2/hr	1.542E-04	cm2/sec
Retarded Lateral Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec
Retarded Vertical Dispersion Coefficient:	5.767E-06	m2/hr	1.601E-05	cm2/sec

Dispersivities	Meters	Feet
Longitudinal:	6.300E+00	2.066E+01
Lateral:	6.300E-01	2.066E+00
Vertical:	6.300E-01	2.066E+00

Load	Begin (m)	End (m)	Begin (ft)	End (ft)
X:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Y:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Z:	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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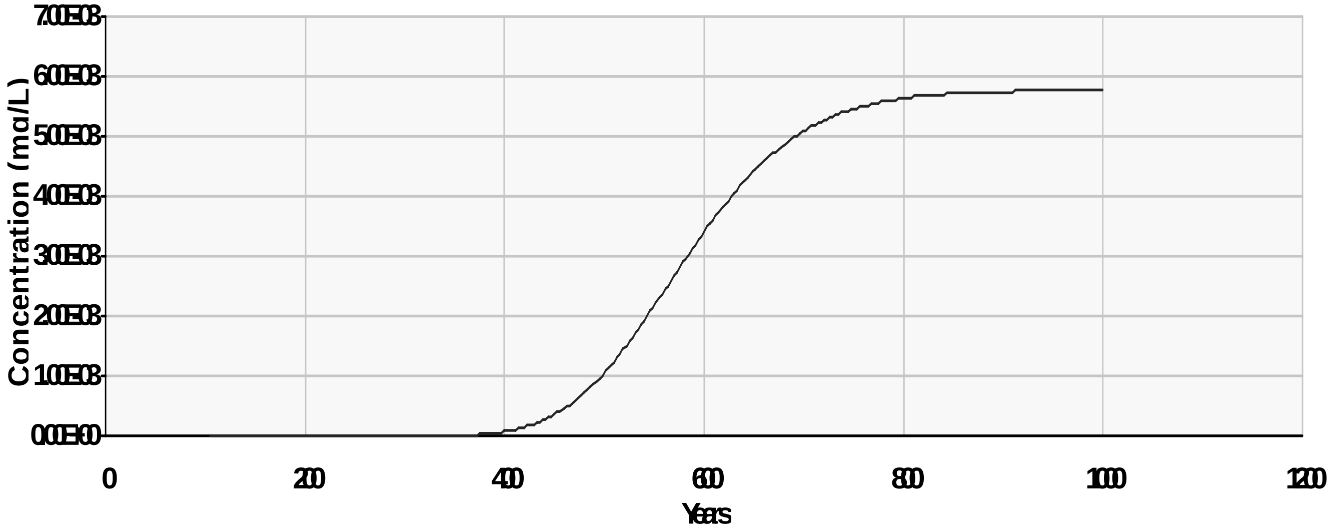
AT123D Point of Compliance Report

no biodeg

no biodeg



Maximum Concentration: 5.770E-03 mg/L

Year of Maximum Concentration: 954.00

Output Coordinates

X:	189.00000 m	620.0712 ft	**Output Time Step:**	0.2500 years	3.0016 months
Y:	0.00000 m	0.0000 ft	**Initial Load (mg/kg):**	0.0000E+00	
Z:	0.00000 m	0.0000 ft	**Initial Load (kg):**	0.7300E+03	

Input Parameters

Porosity:	0.30000	**Soil Organic Carbon Content (percent):**	0.00000	
Hydraulic Gradient:	0.00097	**Carbon Adsorption Coeff. (ug/g)/(ug/ml):**	0.0000E+00	

Hydraulic Conductivity:	6.800E-01	m/hr	1.888E-02	cm/sec
Soil Bulk Density:	1.380E+03	kg/m3	1.380E+00	g/cm3
Aquifer Width:	Infinite	m	Infinite	ft
Aquifer Depth:	3.080E+01	m	1.010E+02	ft
Kd:	7.080E-03	m3/kg	7.080E+00	(ug/g)(ug/ml)
Molecular Diffusion:	2.383E-06	m2/hr	6.619E-06	cm2/sec
Decay Coefficient:	0.000E+00	1/hr	0.000E+00	1/day

Retardation Factor:	3.357E+01			
Retarded Darcy Velocity:	6.550E-05	m2/hr	1.819E-04	cm2/sec
Retarded Longitudinal Disp. Coefficient:	4.129E-04	m2/hr	1.146E-03	cm2/sec
Retarded Lateral Dispersion Coefficient:	4.150E-05	m2/hr	1.152E-04	cm2/sec
Retarded Vertical Dispersion Coefficient:	4.150E-05	m2/hr	1.152E-04	cm2/sec

Dispersivities	**Meters**	**Feet**
Longitudinal:	6.300E+00	2.066E+01
Lateral:	6.300E-01	2.066E+00
Vertical:	6.300E-01	2.066E+00

Load	Begin (m)	End (m)	Begin (ft)	End (ft)
X:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Y:	-1.524E+00	1.524E+00	-4.999E+00	4.999E+00
Z:	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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APPENDIX C

RISK-BASED REMEDIAL GOAL OPTION EVALUATION - SITE 3

Description of Remedial Goal Option Evaluation

Appendix C
Risk-Based Remedial Goal Option Evaluation - Site 3
Former Cedar Chemical Facility

Introduction

To support the remedial action objectives (RAOs) for the Feasibility Study (FS), site-specific cleanup criteria were calculated for each of the likely exposure pathway scenarios. These cleanup criteria or remedial goal options (RGOs) were calculated using the U.S. Environmental Protection Agency (USEPA) guidance documents for human health risk assessment for Superfund sites and for soil screening. RGOs were calculated using formulas provided in the USEPA guidance documents and using inputs applicable to specific site conditions.

Chemical-specific, risk-based RGOs are concentration levels for individual chemicals for specific medium and land use combinations for chemicals identified as chemicals of concern (COCs) due to their potential for contact with and health risk to human receptors.

Historical Site Risk Evaluation

Dinoseb was selected as a COC for subsurface soil for Site 3 in the 2001 Ensafe risk assessment (RA) for the Former Cedar Chemical facility (Ensafe Inc., 2001). Ensafe used samples collected from 0-1 foot below ground surface (bgs) to represent surface soils and samples collected from 0-10 feet bgs to represent subsurface soils. Dinoseb was identified as a COC in the 2001 RA based on a detection of 13,000 milligrams per kilogram (mg/kg) in subsurface soil. Of five detections in subsurface soil, this detection was the only one that exceeded the USEPA Region 6 medium-specific soil screening level (MSL; 680 mg/kg in 2001). Surface soil samples were not collected from Site 3 for use in the 2001 Ensafe RA.

AECOM Site Investigation

To confirm the historic concentration of dinoseb detected at Site 3, AECOM conducted confirmation soil sampling at Site 3 in March 2009. This sampling confirmed the presence of dinoseb at Site 3, but at much lower concentrations than the 13,000 mg/kg reported in the 2001 Ensafe RA. While the concentrations were below the industrial risk-based screening level for an industrial worker (USEPA Region 6 MSL for dinoseb in industrial soil – 620 mg/kg), they did exceed the USEPA Region 6 MCL-based soil screening level (SSL; 0.051 mg/kg) for the protection of groundwater as a drinking water source (AECOM, 2009). The MCL-based SSL is based on the USEPA Soil Screening Guidance (USEPA, 1996) and estimates the concentration of dinoseb in soil that would be protective of groundwater as a residential drinking water source.

Current Risk-Based RGO Evaluation

This RGO evaluation reviews exposure pathways that are based on site-specific conditions, which were not reviewed for dinoseb in the 2001 RA (EnSafe, Inc., 2001), and cannot be addressed through the use of the Region 6 MSLs. RGOs were developed for chemicals identified as contributing to unacceptable risk levels (contaminants of concern (COCs)) in the 2001 Ensafe RA. The RA did not identify dinoseb as a COC for perched or alluvial groundwater and consequently did not calculate an RGO for groundwater exposures. This evaluation of RGOs evaluates site-specific pathways that would be protective of the most likely exposure pathways to humans to dinoseb in soil at Site 3. These pathways include:

- Exposure to dinoseb in soil by an on-site construction worker during digging or excavation;
- Migration of dinoseb in soil to perched groundwater where it could be contacted by an on-site construction worker during digging or excavation;
- Migration of dinoseb in soil to alluvial groundwater and exposure of an off-site agricultural worker during crop irrigation; and
- Migration of dinoseb in soil to alluvial groundwater and exposure of an off-site resident using groundwater as potable water.

On-site residential exposure pathways were not evaluated because the Former Cedar Chemical facility has been recognized by the Arkansas Department of Environmental Quality (ADEQ) as an industrial facility and as likely to remain industrial (ADEQ, 2005). On-site risk-based RGOs for on-site industrial exposures (not construction-related exposure) are not included in this evaluation because the screening values developed by USEPA Region 6 for an outdoor industrial worker are recognized as sufficiently protective of this exposure pathway.

RGO Calculation Methodology

RGOs were calculated using USEPA guidance documents for human health risk assessment for Superfund sites and for soil screening. RGOs were calculated using formulas provided in the following USEPA guidance documents:

- *Risk Assessment Guidance for Superfund (RAGS), Volume 1, Human Health Evaluation Manual, Interim Final* (USEPA, December 1989); and
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, December 2002).

The following formula was used to calculate an RGO for the on-site construction worker exposed to dinoseb in soil during digging or excavation.

$$RGO_{const\ wkr} = \frac{THQ \times BW \times ATN}{EF \times ED \times (A + B + C)}$$

Where:

THQ = target hazard quotient
BW = body weight
ATN = averaging time, noncarcinogens (ED x 365 days/year)
EF = exposure frequency
ED = exposure duration

A = ingestion pathway $\left(\dfrac{IR \times FI \times CF}{RfD_o}\right)$

IR = daily soil ingestion rate
FI = fraction of soil ingested
CF = conversion factor
RfD_o = oral reference dose

B = dermal pathway $\left(\dfrac{AF \times ABS \times SA \times CF}{RfD_d}\right)$

AF = soil-to-skin adherence factor
ABS = soil absorption factor
SA = exposed skin surface area
CF = conversion factor
GIABS = gastrointestinal absorption factor
RfD_d = dermal reference dose (RfDo * GIABS)

C = inhalation pathway (not evaluated because an inhalation reference dose is not available)

The following formula was used to calculate an RGO for the on-site construction worker exposed to dinoseb that migrates from soil to groundwater.

$$RGO_{const\ wkr} = \frac{THQ \times BW \times ATN}{EF \times ED \times (A + B + C)}$$

Where:

THQ = target hazard quotient
BW = body weight
ATN = averaging time, noncarcinogens (ED x 365 days/year)
EF = exposure frequency
ED = exposure duration

A = ingestion pathway $\left(\dfrac{IR}{RfD_o}\right)$

IR = daily water ingestion rate
RfD_o = oral reference dose

B = dermal pathway $\left(\dfrac{ET \times SA \times PC \times CF}{RfD_d}\right)$

> ET = exposure time
> SA = exposed skin surface area
> PC = permeability coefficient
> CF = conversion factor
> GIABS = gastrointestinal absorption factor
> RfD_d = dermal reference dose (RfD_o * GIABS)

C = inhalation pathway (not evaluated because an inhalation reference dose is not available)

The groundwater RGO is then used as the target groundwater concentration (C_w) to back-calculate a soil RGO that is protective of the on-site construction worker using the following formula:

$$SSL = C_w\left[K_d + \frac{\Theta_w + (\Theta_a \times H')}{\rho_b}\right]$$

Where:

SSL = Soil Screening Level
C_w = target groundwater concentration (mg/L)
K_d = soil/water partition coefficient (K_{oc} x f_{oc})
K_{oc} = organic carbon partition coefficient
f_{oc} = organic carbon content of soil
θ_w = water-filled soil porosity
θ_a = air-filled soil porosity (n - θ_w)
n = total soil porosity ($1 - \rho_b / \rho_s$)
ρ_b = dry soil bulk density
ρ_s = soil particle density
H' = Henry's law constant

The target groundwater concentration (C_w) is adjusted by multiplying the concentration by a dilution attenuation factor (DAF). Migration to the water table generally reduces the contaminant concentration by dilution and attenuation processes such as adsorption and degradation. The contaminant concentration arriving at the water table is generally lower than the original soil concentration. The DAF can be defined as the ratio of the original contaminant concentration to the receptor point concentration. The lowest DAF is a value of one, signifying no dilution or attenuation. A site-specific DAF of 5.41 was calculated for Site 3 using USEPA soil screening guidance (USEP, 1996 and 2002) and Site-specific data. The formulas and parameters used to calculate the site-specific DAF are shown in Table C-1.

The construction worker scenario considered that a worker could be exposed to dinoseb in soil or in perched groundwater while performing excavation activities on the site. USEPA guidance default values were supplemented with inputs applicable to specific Site 3 conditions as well as chemical-specific inputs for dinoseb. An exposure time of 8 hours per day was assumed to be the number of hours the construction worker would be on site each work day. A skin surface area of 4100 square centimeters

(cm^2) was based on the surface area of the head, hands, and forearms (the body parts expected to be exposed). The EF of 60 days per year and ED of one year assume the worker will work 12 weeks at the site over the course of one year. The complete lists of parameters and sources used to evaluate the exposure of the construction worker are shown in Table C-2 (direct contact with soil) and Table C-3 (direct contact with perched groundwater).

The formulas used to calculate the groundwater RGO and to back-calculate the soil RGO protective of an off-site agricultural worker exposed to dinoseb that migrates from soil to groundwater are the same as those shown above for the on-site construction worker. While the formula for back-calculating the soil RGO takes a DAF into account, it does not describe the transport of the contaminant in the saturated zone to an off-site supply well, and it does not consider advection, dispersion, or decay. Parameters used for the agricultural worker that are different from those used for the construction worker include ingestion rate and exposure frequency, duration, and time. An EF of 18 days per year is based on local flood irrigation practices. Irrigation is required during the summer months of June, July, and August and occurs once every 10 days (nine events). Each event requires two days of irrigation with an assumed ET of one hour per day in the field. An ED of 25 years is the number of years over which exposure occurs. The complete list of parameters used to evaluate the exposure of an off-site agricultural worker is shown in Table C-4.

The residential groundwater exposure scenario was evaluated using two existing screening criteria as the target groundwater concentrations for calculation of soil RGOs protective of groundwater as a drinking water source. The maximum contaminant level (MCL; USEPA, 2006) of 7 ug/L was used to determine an MCL-based soil RGO and the Region 6 MSL (USEPA, 2008) was used to determine a risk-based soil RGO. The formula used is the SSL portion of the formulas shown above for the construction worker exposed to groundwater. As with the agricultural scenario, the residential scenario does not consider advection, dispersion, or decay. In other words, the formula very conservatively assumes that receptor wells would be on top of Site 3 and not transported to an off-site drinking or agricultural-use water well. The parameters used to evaluate both of the residential groundwater exposures are shown in Table C-5.

Summary and Conclusions

The RGOs calculated for Site 3 are shown in Table C-6 and summarized below:

Risk-Based RGOs for Dinoseb in Soil at Site 3

Land Use/Receptor	Direct Contact (mg/kg)	Protection of Groundwater (mg/kg)
Soil		
Industrial (Construction Worker)[1]	739	11
Agricultural Worker[2]	NA	294
Residential (MCL-Based)[3]	NA	0.28
Residential (Risk-Based)[3]	NA	1.5

NOTES:

1. The direct contact RGO (on-Site construction worker receptor) is based on the potential exposure of the future construction worker to subsurface soil at Site 3. The protection of groundwater RGO (on-Site construction worker receptor) is based on potential exposure of the future construction worker to perched zone water during construction activities.
2. The protection of groundwater RGO (off-Site agricultural worker receptor) is based on potential exposure of an agricultural worker to alluvial aquifer groundwater from an off-Site agricultural well.
3. The protection of groundwater RGO (off-Site resident receptor) is based on potential exposure of a resident to alluvial aquifer groundwater from a potable water well.

NA = not applicable

These values were calculated as described above and using the USEPA guidance default and chemical- and site-specific values shown in Tables C-2 through C-5. The Soil Screening Guidance model used for estimation of concentrations of dinoseb leaching from soil to groundwater does not take into account fate and transport of leachate in the vadose zone and can be excessively conservative for highly volatile or highly sorptive chemicals. Therefore, the soil RGOs that were calculated using the simplistic DAF (calculated using the Soil Screening Guidance [USEPA, 2002]) are likely to be conservative values that overestimate the potential for exposure and related risk.

References

AECOM 2009. *Wormald Site Investigation Report, Tyco Safety Products – Former Cedar Chemical Facility*, Helena-West Helena, Arkansas. May 21.

ADEQ 2004. *Comprehensive Site Assessment; Cedar Chemical Corporation Plant Site*. Brownfield Program. April.

Ensafe 2001. *Risk Assessment for Cedar Chemical Corporation – West Helena, Arkansas*. March 21.

USEPA 1989. *Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part A) Interim Final*. Washington, DC. Office of Emergency and Remedial Response. December.

USEPA 1996. *Soil Screening Guidance: User's Guide*. Washington, DC. Office of Solid Waste and Emergency Response. July.

USEPA 2000. *Region VI Human Health Medium-Specific Screening Levels*. USEPA Region VI: Dallas, Texas. October.

USEPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*. Washington, DC. Office of Emergency and Remedial Response. December.

USEPA 2006. *2006 Edition of the Drinking Water Standards and Health Advisories*. Washington, DC. Office of Water. August.

USEPA 2008. Region 6 Human Health Medium-Specific Screening Level Table. September.

Summary Tables

Table C-1
Derivation of Dilution Attenuation Factor (DAF)
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

Dilution Attenuation Factor (Equation B-14, USEPA 2002):

$$\boxed{DAF = 1 + \frac{K * i * d}{I * L}}$$

Where:

Parameter	Definition	Original Value	Original Units	Value	Units	Reference
K	aquifer hydraulic conductivity	1.90E-02	cm/sec	5.99E+03	m/yr	Average value for the Alluvial Aquifer based on step drawdown tests (Table 5, FI, AMEC Geomatrix, February 2009)
i	hydraulic gradient	0.00097	ft/ft	0.00097	m/m	Calculated for the Site 3 area based on July 2008 Alluvial Aquifer Potentiometric Map (Fig 10, AMEC Geomatrix, Feb 2009)
I	infiltration rate			1.80E-01	m/yr	Default value from Region 6 SSL calculation website: http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search
d	mixing zone depth	1.00	m	1.00	m	Calculated using Equation B-15, USEPA 2002 below
L	source length parallel to groundwater flow	24	ft/ft	7.32E+00	m	Calculated from surfer figure showing exceedances of industrial MSL (620 ppm) - uses historic concentration of dinoseb (13,000 ppm) at 3 SB-6
d_a	aquifer thickness	101	feet	3.08E+01	m	Log for 4 MW-4 (Ensafe, 1996) which is just SE of Site 3 and nearest deep boring to Site 3; (EnSafe 2001 RA uses 34.8 m as d_a)

Table C-1
Derivation of Dilution Attenuation Factor (DAF)
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

Estimation of Mixing Zone Depth (Equation B-15, USEPA 2002):

$$\boxed{d = \left(0.0112L^2\right)^{0.5} + d_a\left(1 - \exp\left[\frac{(-L*I)}{(K*i*d_a)}\right]\right)}$$

d =	**1.00**	meters
DAF =	**5.41**	unitless

References:

AMEC Geomatrix 2009. Facility Investigation Report, Cedar Chemical Corporation, Helena-West Helena, Arkansas. February.

Ensafe, Inc., 1996. Facility Investigation, Cedar Chemical Company. (Phase I through III). June 28.

United States Environmental Protection Agency (USEPA) 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2009. Regional Screening Levels for Chemical Contaminants at Superfund Sites. USEPA Region 6 Soil Screening Level website accessed at http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search.

Table C-2
Values Used For Calculating Remedial Goal Option (RGO) for a Construction Worker Exposed to Soil
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference
Ingestion	Construction Worker	Adult	Soil	IRSOIL	Ingestion Rate, soil	330	mg/day	USEPA 2002
				FI	Fraction Ingestion from Source	1	unitless	USEPA 2000
				EF	Exposure Frequency	60	days/year	USEPA 1989
				ED	Exposure Duration	1	years	USEPA 2002
				CF	Conversion Factor	0.000001	kg/mg	--
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	365	days	ED x 365 d/y
Dermal	Construction Worker	Adult	Soil	SA	Skin surface area for contact	4100	cm2/day	USEPA 2004 (Head, hands, and forearms)
				AF	Soil-to-skin adherence factor	0.3	mg/cm2	USEPA 2002
				ABS	Soil Absorption Factor	0.1	unitless	USEPA 2004
				EF	Exposure Frequency	60	days/year	USEPA 1989
				ED	Exposure Duration	1	years	USEPA 2002
				CF	Conversion Factor	0.000001	kg/mg	--
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	365	days	ED x 365 d/y
Inhalation	Construction Worker	Adult	Particulates from Soil	PEF	Particulate Emission Factor	1.36E+10	m3/kg	USEPA 2002
				INHR	Inhalation Rate	0.833	m3/hr	USEPA 2000
				ET	Exposure Time	8	hr/day	Professional Judgment
				EF	Exposure Frequency	60	days/year	USEPA 1989
				ED	Exposure Duration	1	years	USEPA 2002
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	365	days	ED x 365 d/y

$$\textbf{RGO (mg/kg)} = \frac{(THQ \times BW \times ATN)}{(EF \times ED) \times [\,(1/RfDo \times IRSOIL \times FI \times CF) + (1/(RfDo*GIABS) \times AF \times ABS \times SA \times CF) + (1/RfDi \times 1/PEF \times INHR \times ET)\,]}$$

Where:

	Value	Units	Rationale/Reference
THQ (Target Hazard Quotient) =	1	unitless	--
RfDo (Oral Reference Dose) =	0.001	mg/kg-day	USEPA 2009
RfDi (Inhalation Reference Dose) =	Not Available	mg/kg-day	--
GIABS (Gastrointestinal Absorption Factor) =	0.5	unitless	USEPA 2004

RGO (mg/kg) = 739

References:

United States Environmental Protection Agency (USEPA) 1989. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part A) Interim Final. (EPA/540/1/89/002). Washington, DC. Office of Emergency and Remedial Response.

USEPA 2000. Supplemental Guidance to RAGS: Region 4 Bulletins – Human Health Risk Assessment (Interim). Waste Management Division, Office of Health Assessment, USEPA Region 4, Atlanta, Georgia.

USEPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2004. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Washington, DC. Office of Superfund Remediation and Technology Innovation.

USEPA 2009. Integrated Risk Information System accessed online at http://cfpub.epa.gov/ncea/iris/index.cfm.

Table C-3
Values Used For Calculating Remedial Goal Option (RGO) for a Construction Worker Exposed to Groundwater
Reasonable Maximum Exposure
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference
Ingestion	Construction Worker	Adult	Groundwater	IRGW	Ingestion Rate, groundwater	0.08	L/day	8 hr/day x 10 ml/hr (USEPA 2000)
				EF	Exposure Frequency	60	days/year	USEPA 1989
				ED	Exposure Duration	1	years	USEPA 2002
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	365	days	ED x 365 d/y
Dermal	Construction Worker	Adult	Groundwater	SA	Body Area Available for Contact	4100	cm2	USEPA 2004 (Head, hands, and forearms)
				ET	Exposure Time	8	hr/day	Site Specific
				EF	Exposure Frequency	60	days/year	USEPA 1989
				ED	Exposure Duration	1	years	USEPA 2002
				PC	Dermal Permeability Coefficient	0.022	cm/hr	ORNL 2009
				CF	Conversion Factor	0.001	L/cm3	--
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	365	days	ED x 365 d/y

$$\textbf{RGO (mg/L)} = \frac{(THQ \times BW \times ATN)}{(EF \times ED) \times [\,(1/RfDo \times IRGW) + (1/(RfDo*GIABS) \times SA \times ET \times PC \times CF)\,]}$$

Where:

	Value	Units	Rationale/Reference
THQ (Target Hazard Quotient) =	1	unitless	--
RfDo (Oral Reference Dose) =	0.001	mg/kg-day	USEPA 2009
GIABS (Gastrointestinal Absorption Factor) =	0.5	unitless	USEPA 2004

RGO (mg/L) = 0.280

The groundwater RGO is then used as the target groundwater concentration (Cw) along with the dilution attenuation factor (DAF) to back-calculate a Soil RGO:

$$\textbf{RGO (mg/kg)} = Cw \times [\; Kd + (\;(\theta w + (\theta a \times H')\;)\;/\;\rho b\;)\;]$$

Where:

	Value	Units	Rationale/Reference
Cw = target groundwater concentration (DAF x Water RGO which was calculated above) =	1.51	mg/L	Calculated
DAF =	5.41	unitless	See Table 1
Water RGO =	0.28	mg/L	Calculated Above
Kd = soil/water partition coefficient (Koc x foc) =	7.08	L/kg	Calculated
Koc = organic carbon partition coefficient =	3540	L/kg	ORNL 2009
foc = organic carbon content of soil =	0.002	kg/kg	USEPA 2002
θw = water-filled soil porosity =	0.3	L/L	USEPA 2002
θa = air-filled soil porosity (1 - [ρb/ρs] - θw) =	0.13	unitless	Calculated
ρb = dry soil bulk density =	1.5	kg/L	USEPA 2002
ρs = soil particle density =	2.65	kg/L	USEPA 2002
H' = Henry's law constant =	0.00000186	unitless	ORNL 2009

RGO (mg/kg) = 11

Table C-3
Values Used For Calculating Remedial Goal Option (RGO) for a Construction Worker Exposed to Groundwater
Reasonable Maximum Exposure
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

References:

Oak Ridge National Laboratory (ORNL) 2009. Risk Assessment Information System accessed online at http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem.

United States Environmental Protection Agency (USEPA) 1989. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part A) Interim Final. (EPA/540/1/89/002). Washington, DC. Office of Emergency and Remedial Response.

USEPA 2000. Supplemental Guidance to RAGS: Region 4 Bulletins – Human Health Risk Assessment (Interim). Waste Management Division, Office of Health Assessment, US EPA Region 4, Atlanta, Georgia.

USEPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2004. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Washington, DC. Office of Superfund Remediation and Technology Innovation.

USEPA 2009. Integrated Risk Information System accessed online at http://cfpub.epa.gov/ncea/iris/index.cfm.

Table C-4
Values Used For Calculating Remedial Goal Option (RGO) for an Agricultural Worker Exposed to Groundwater During Crop Irrigation
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference
Ingestion	Agricultural Worker	Adult	Groundwater	IRGW	Ingestion Rate, groundwater	0.01	L/day	1 hr/day x 10 ml/hr (USEPA 2000)
				EF	Exposure Frequency	18	days/year	Professional Judgment
				ED	Exposure Duration	25	years	USEPA 1989
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	9125	days	ED x 365 d/y
Dermal	Agricultural Worker	Adult	Groundwater	SA	Body Area Available for Contact	4100	cm2	USEPA 2004 (head, hands, forearms)
				ET	Exposure Time	1	hr/day	Professional Judgment
				EF	Exposure Frequency	18	days/year	Professional Judgment
				ED	Exposure Duration	25	years	USEPA 1989
				PC	Dermal Permeability Coefficient	0.022	cm/hr	ORNL 2009
				CF	Conversion Factor	0.001	L/cm3	--
				BW	Body Weight	70	kg	USEPA 2002
				ATN	Averaging Time, noncarcinogens	9125	days	ED x 365 d/y

RGO (mg/L) =

$$\frac{(THQ \times BW \times ATN)}{(EF \times ED) \times [\,(1/RfDo \times IRGW) + (1/(RfDo*GIABS) \times SA \times ET \times PC \times CF)\,]}$$

Where:	Value	Units	Rationale/Reference
THQ (Target Hazard Quotient) =	1	unitless	--
RfDo (Oral Reference Dose) =	0.001	mg/kg-day	USEPA 2009
GIABS (Gastrointestinal Absorption Factor) =	0.5	unitless	USEPA 2004

RGO (mg/L) = **7.46**

The groundwater RGO is then used as the target groundwater concentration (Cw) along with the dilution attenuation factor (DAF) to back-calculate a Soil RGO:

RGO (mg/kg) = $Cw \times [\ Kd + (\ (\theta w + (\theta a \times H')\ )\ /\ \rho b\ )\ ]$

Where:	Value	Units	Rationale/Reference
Cw = target groundwater concentration (DAF x Water RGO which was calculated above) =	40.33	mg/L	Calculated
DAF =	5.41	unitless	See Table 1
Water RGO =	7.46	mg/L	Calculated Above
Kd = soil/water partition coefficient (Koc x foc) =	7.08	L/kg	Calculated
Koc = organic carbon partition coefficient =	3540	L/kg	ORNL 2009
foc = organic carbon content of soil =	0.002	kg/kg	USEPA 2002
θw = water-filled soil porosity =	0.3	L/L	USEPA 2002
θa = air-filled soil porosity (1 - [ρb/ρs] - θw) =	0.13	unitless	Calculated
ρb = dry soil bulk density =	1.5	kg/L	USEPA 2002
ρs = soil particle density =	2.65	kg/L	USEPA 2002
H' = Henry's law constant =	0.00000186	unitless	ORNL 2009

RGO (mg/kg) = **294**

Table C-4
Values Used For Calculating Remedial Goal Option (RGO) for an Agricultural Worker Exposed to Groundwater During Crop Irrigation
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

References:

Oak Ridge National Laboratory (ORNL) 2009. Risk Assessment Information System accessed online at http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem.

United States Environmental Protection Agency (USEPA) 1989. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part A) Interim Final. (EPA/540/1/89/002). Washington, DC. Office of Emergency and Remedial Response.

USEPA 2000. Supplemental Guidance to RAGS: Region 4 Bulletins – Human Health Risk Assessment (Interim). Waste Management Division, Office of Health Assessment, US EPA Region 4, Atlanta, Georgia.

USEPA 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2004. Risk Assessment Guidance for Superfund - Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Washington, DC. Office of Superfund Remediation and Technology Innovation.

USEPA 2009. Integrated Risk Information System accessed online at http://cfpub.epa.gov/ncea/iris/index.cfm.

Table C-5
Values Used For Calculating Remedial Goal Option (RGO) for a Resident Exposed to Groundwater from a Potable Water Well
Former Cedar Chemical Facility - Site 3
Helena - West Helena, Arkansas

RGO (mg/kg) = $Cw \times [\ Kd + (\ (\theta w + (\theta a \times H')\ )\ /\ \rho b\ )\ ]$

Based on the Drinking Water Standard, Maximum Contaminant Level of 0.007 mg/L

Where:			
Cw = target groundwater concentration (DAF x MCL) =	0.038	mg/L	Calculated
DAF =	5.41	unitless	See Table 1
MCL =	0.007	mg/L	USEPA 2006
Kd = soil/water partition coefficient (Koc x foc) =	7.08	L/kg	Calculated
Koc = organic carbon partition coefficient =	3540	L/kg	ORNL 2009
foc = organic carbon content of soil =	0.002	kg/kg	USEPA 2002
θw = water-filled soil porosity =	0.3	L/L	USEPA 2002
θa = air-filled soil porosity (1 - [ρb/ρs] - θw) =	0.13	unitless	Calculated
ρb = dry soil bulk density =	1.5	kg/L	USEPA 2002
ρs = soil particle density =	2.65	kg/L	USEPA 2002
H' = Henry's law constant =	0.00000186	unitless	ORNL 2009

MCL-Based RGO (mg/kg) = 0.28

Based on the EPA Region 6 Risk-Based Medium Screening Level of 0.037 mg/L

Where:			
Cw = target groundwater concentration (DAF x MCL) =	0.200	mg/L	Calculated
DAF =	5.41	unitless	See Table 1
MSL =	0.037	mg/L	USEPA 2009
Kd = soil/water partition coefficient (Koc x foc) =	7.08	L/kg	Calculated
Koc = organic carbon partition coefficient =	3540	L/kg	ORNL 2009
foc = organic carbon content of soil =	0.002	kg/kg	USEPA 2002
θw = water-filled soil porosity =	0.3	L/L	USEPA 2002
θa = air-filled soil porosity (1 - [ρb/ρs] - θw) =	0.13	unitless	Calculated
ρb = dry soil bulk density =	1.5	kg/L	USEPA 2002
ρs = soil particle density =	2.65	kg/L	USEPA 2002
H' = Henry's law constant =	0.00000186	unitless	ORNL 2009

Risk-Based RGO (mg/kg) = 1.5

References:

Oak Ridge National Laboratory (ORNL) 2009. Risk Assessment Information System accessed online at http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem.

United States Environmental Protection Agency (USEPA) 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2006. 2006 Edition of the Drinking Water Standards and Health Advisories. Washington, DC. Office of Water.

USEPA 2008. Region 6 Human Health Medium-Specific Screening Level Table.

APPENDIX D

DETAILED COST ESTIMATES FOR REMEDIAL ALTERNATIVES

Alternative 1 – No Action

Table D-1A
Cost Estimate Summary for Alternative 1
No Action
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Cost Estimate for Alternative 1	Task	01		
Description		5-Year Remedy Review Years 5 and 10		
	Year *	5		
Labor Category	Units	Hrs	Rate	Cost
Principal	hr	-	155.00	-
Senior Professional III	hr	-	142.00	-
Senior Professional II	hr	-	130.00	-
Senior Professional I - PM	hr	-	120.00	-
Project Professional II	hr	-	105.00	-
Project Professional I	hr	8	100.00	800.00
Staff Professional II	hr	-	85.00	-
Staff Professional I	hr	-	80.00	-
Technician III	hr	8	65.00	520.00
Technician II	hr	-	60.00	-
Technician I	hr	-	55.00	-
Equipment Operator	hr	-	65.00	-
CAD/GIS Operator II	hr	4	80.00	320.00
CAD/GIS Operator I	hr	-	65.00	-
Draftman/Illustrator	hr	-	55.00	-
Project Professional VII	hr	-	100.00	-
Staff Professional V	hr	-	85.00	-
Professional III	hr	24	75.00	1,800.00
Professional I	hr	-	70.00	-
Project Administrator II	hr	-	63.00	-
Project Administrator I	hr	-	58.00	-
Total Labor[1]		**44**		**3,440.00**
Travel/Transportation	**Unit**	**Qty**	**Rate**	**Cost**
Airfare	rate	-	500.00	-
Car Rental/Gas	day	2	75.00	150.00
Lodging	day	1	70.00	70.00
Per diem	day	2	39.00	78.00
Total Travel/Transportation[2]				**298.00**
Other Direct Costs	**Unit**	**Qty**	**Rate**	**Cost**
Production		2	50.00	100.00
Shipping		2	25.00	50.00
Total Other Direct Costs				**150.00**
Total Non-Labor Costs				**448.00**
G & A (on Non-Labor Only)				44.80
Total Labor & Non-Labor				**3,932.80**
Profit (on Labor & Non-Labor)				393.28
Subtotal Costs				**4,326.08**
TOTAL				**4,326.08**

Notes:
[1] - Labor costs were estimated using professional judgment based on similar projects conducted by AECOM
[2] - Travel and Transportation costs estimated using current government per diem rates.

TABLE D-1B
PRESENT WORTH (PW) COST FOR ALTERNATIVE 1
NO ACTION

Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	5-YEAR REMEDY REVIEW COSTS					
1.00	**5-Year Remedy Review**					
1.01	Year 5	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**
1.02	Year 10	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**

PW for Remedy Review **10 Yrs** **$ 7,008**

Inputs

Inflation Rate **4.00%**

Interest Rate **7.00%**

Year	Inf. Factor	PWF	PW O&M Cost
1	1.0400	0.9346	$0
2	1.0816	0.8734	$0
3	1.1249	0.8163	$0
4	1.1699	0.7629	$0
5	1.2167	0.7130	$3,753
6	1.2653	0.6663	$0
7	1.3159	0.6227	$0
8	1.3686	0.5820	$0
9	1.4233	0.5439	$0
10	1.4802	0.5083	$3,255

Alternative 2 – Institutional Controls

Table D-2A
Cost Estimate Summary for Alternative 2
Institutional Controls
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Cost Estimate for Alternative 2	Task	01			02A			02B			Total Cost	
Description		5-Year Remedy Review Years 5 and 10			Institutional Controls Implementation (Year 1)			Institutional Controls O&M - Years 2 through 10				
	Year *	5			0			0				
Labor Category	**Units**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Cost**
Principal	hr	-	155.00	-	-	155.00	-	-	155.00	-	-	-
Senior Professional III	hr	-	142.00	-	-	142.00	-	-	142.00	-	-	-
Senior Professional II	hr	-	130.00	-	-	130.00	-	-	130.00	-	-	-
Senior Professional I - PM	hr	-	120.00	-	-	120.00	-	-	120.00	-	-	-
Project Professional II	hr	-	105.00	-	-	105.00	-	-	105.00	-	-	-
Project Professional I	hr	8	100.00	800.00	8	100.00	800.00	-	100.00	-	16	1,600.00
Staff Professional II	hr	-	85.00	-	-	85.00	-	-	85.00	-	-	-
Staff Professional I	hr	-	80.00	-	-	80.00	-	-	80.00	-	-	-
Technician III	hr	8	65.00	520.00	2	65.00	130.00	-	65.00	-	10	650.00
Technician II	hr	-	60.00	-	-	60.00	-	-	60.00	-	-	-
Technician I	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	-
Equipment Operator	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	-
CAD/GIS Operator II	hr	4	80.00	320.00	2	80.00	160.00	-	80.00	-	6	480.00
CAD/GIS Operator I	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	-
Draftsman/Illustrator	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	-
Project Professional VII	hr	-	100.00	-		100.00	-		100.00	-	-	-
Staff Professional V	hr	-	85.00	-		85.00	-		85.00	-	-	-
Professional III	hr	24	75.00	1,800.00	-	75.00	-	20	75.00	1,500.00	24	1,800.00
Professional I	hr	-	70.00	-		70.00	-		70.00	-	-	-
Project Administrator II	hr	-	63.00	-	-	63.00	-	-	63.00	-	-	-
Project Administrator I	hr	-	58.00	-	-	58.00	-	-	58.00	-	-	-
Total Labor[1]		**44**		**3,440.00**	**12**		**1,090.00**	**20**		**1,500.00**	**56**	**4,530.00**
Travel/Transportation	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Airfare	rate	-	500.00	-	-	500.00	-	-	500.00	-	-	-
Car Rental/Gas	day	2	75.00	150.00	-	75.00	-	2	75.00	150.00	2	150.00
Lodging	day	1	70.00	70.00	-	70.00	-	1	70.00	70.00	1	70.00
Per diem	day	2	39.00	78.00	-	39.00	-	2	39.00	78.00	2	78.00
Total Travel/Transportation[2]				**298.00**			**-**			**298.00**		**298.00**
Other Direct Costs	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Production		2	50.00	100.00	1	50.00	50.00	-	50.00	-	3	150.00
Shipping		2	25.00	50.00	-	25.00	-	-	25.00	-	2	50.00
Total Other Direct Costs				**150.00**			**50.00**			**-**		200.00
Total Non-Labor Costs				**448.00**			**50.00**			**298.00**		498.00
G & A (on Non-Labor Only)				44.80			5.00			29.80		49.80
Total Labor & Non-Labor				**3,932.80**			**1,145.00**			**1,827.80**		**5,077.80**
Profit (on Labor & Non-Labor)				393.28			114.50			182.78		507.78
Subtotal Costs				**4,326.08**			**1,259.50**			**2,010.58**		**5,585.58**
Subcontractors	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Phillips County Recorder Fees	LS	-	150.00	-	1	150.00	150.00	-	150.00	-	1	150.00
Legal Fees	LS	-	1,000.00	-	1	1,000.00	1,000.00	-	1,000.00	-	1	1,000.00
Fence Maintenance & Repair	LS	-	500.00	-	-	500.00	-	1	500.00	500.00	1	500.00
Subtotal Subcontractors[3]				**-**			**1,150.00**			**500.00**		1,150.00
Management fee (on subs only)				-			80.50			35.00		80.50
Total Subcontractors				**-**			**1,230.50**			**535.00**		**1,230.50**
TOTAL				**4,326.08**			**2,490.00**			**2,545.58**		**6,816.08**

Notes:
* 0 for Base Year; 1, 2, 3 for respective option years.
[1] - Labor costs were estimated using professional judgment based on similar projects conducted by AECOM.
[2] - Travel and Transportation costs estimated using current government per diem rates.
[3] - Phillips County Recorder fees per telephone communication with the Phillips County Recorders office; costs are $15 for the first page and $5 for each additional page; estimate assumes 28 pages. Costs for other subcontractors were estimated using professional judgment based on similar projects conducted by AECOM.

TABLE D-2B
PRESENT WORTH (PW) COSTS FOR ALTERNATIVE 2
INSTITUTIONAL CONTROLS
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	5-YEAR REMEDY REVIEW COSTS					
1.00	**5-Year Remedy Review**					
1.01	Year 5	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**
1.02	Year 10	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**

PW for Remedy Review **10 Yrs** **$ 7,008**

Inputs

		Year	Inf. Factor	PWF	PW O&M Cost
Inflation Rate	**4.00%**	**1**	1.0400	0.9346	$0
		2	1.0816	0.8734	$0
Interest Rate	**7.00%**	**3**	1.1249	0.8163	$0
		4	1.1699	0.7629	$0
		5	1.2167	0.7130	$3,753
		6	1.2653	0.6663	$0
		7	1.3159	0.6227	$0
		8	1.3686	0.5820	$0
		9	1.4233	0.5439	$0
		10	1.4802	0.5083	$3,255

TABLE D-2B
PRESENT WORTH (PW) COSTS FOR ALTERNATIVE 2
INSTITUTIONAL CONTROLS
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	ANNUAL O&M COSTS					
2.00	**Institutional Controls O&M - Years 1 through 10**					
2.01	Year 1	Labor and cost for annual site security inspection	Event	$2,546	0	**$0**
2.02	Year 2	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.03	Year 3	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.04	Year 4	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.05	Year 5	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.06	Year 6	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.07	Year 7	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.08	Year 8	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.09	Year 9	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**
2.10	Year 10	Labor and cost for annual site security inspection	Event	$2,546	1	**$2,546**

PW for Remedy Review

10 Yrs **$ 19,368**

Inputs

Inflation Rate **4.00%**

Interest Rate **7.00%**

Year	Inf. Factor	PWF	PW O&M Cost
1	1.0400	0.9346	$0
2	1.0816	0.8734	$2,405
3	1.1249	0.8163	$2,337
4	1.1699	0.7629	$2,272
5	1.2167	0.7130	$2,208
6	1.2653	0.6663	$2,146
7	1.3159	0.6227	$2,086
8	1.3686	0.5820	$2,028
9	1.4233	0.5439	$1,971
10	1.4802	0.5083	$1,915

Alternative 3 – Institutional Controls with Down-Gradient Groundwater Monitoring

Table D-3A
Cost Estimate Summary for Alternative 3
Institutional Controls with Down-Gradient Groundwater Monitoring
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Cost Estimate for Alternative 3	**Task**	**01**			**02A**			**03**			**Total Cost**	
Description		**5-Year Remedy Review Years 5 and 10**			**Institutional Controls Implementation (Year 1)**			**Groundwater Monitoring (Years 1 through 10)[5]**				
	Year *	**5**			**0**			**0**				
Labor Category	**Units**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Cost**
Principal	hr	-	155.00	-	-	155.00	-	-	155.00	-	-	-
Senior Professional III	hr	-	142.00	-	-	142.00	-	-	142.00	-	-	-
Senior Professional II	hr	-	130.00	-	-	130.00	-	-	130.00	-	-	-
Senior Professional I - PM	hr	-	120.00	-	-	120.00	-	-	120.00	-	-	-
Project Professional II	hr	-	105.00	-	-	105.00	-	-	105.00	-	-	-
Project Professional I	hr	8	100.00	800.00	8	100.00	800.00	8	100.00	800.00	24	2,400.00
Staff Professional II	hr	-	85.00	-	-	85.00	-	-	85.00	-	-	-
Staff Professional I	hr	-	80.00	-	-	80.00	-	-	80.00	-	-	-
Technician III	hr	8	65.00	520.00	2	65.00	130.00	8	65.00	520.00	18	1,170.00
Technician II	hr	-	60.00	-	-	60.00	-	-	60.00	-	-	-
Technician I	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	-
Equipment Operator	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	-
CAD/GIS Operator II	hr	4	80.00	320.00	2	80.00	160.00	4	80.00	320.00	10	800.00
CAD/GIS Operator I	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	-
Draftsman/Illustrator	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	-
Project Professional VII	hr	-	100.00	-		100.00	-	-	100.00	-	-	-
Staff Professional V	hr	-	85.00	-		85.00	-	-	85.00	-	-	-
Professional III	hr	24	75.00	1,800.00	-	75.00	-	60	75.00		84	1,800.00
Professional I	hr	-	70.00	-		70.00	-	-	70.00		-	-
Project Administrator II	hr	-	63.00	-	-	63.00	-	-	63.00	-	-	-
Project Administrator I	hr	-	58.00	-	-	58.00	-	-	58.00	-	-	-
Total Labor[1]		**44**		**3,440.00**	**12**		**1,090.00**	**80**		**1,640.00**	**136**	**6,170.00**
Field Equipment/Supplies	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
GW Monitoring Equipment & Supplies	LS	-	2,400.00	-	-	2,400.00	-	1	2,400.00	2,400.00	1	2,400.00
Total Field Equip/Supplies[2]				**-**			**-**			**2,400.00**		**2,400.00**
Travel/Transportation	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Airfare	rate	-	500.00	-	-	500.00	-	-	500.00	-	-	-
Car Rental/Gas	day	2	75.00	150.00	-	75.00	-	3	75.00	225.00	5	375.00
Lodging	day	1	70.00	70.00	-	70.00	-	4	70.00	280.00	5	350.00
Per diem	day	2	39.00	78.00	-	39.00	-	6	39.00	234.00	8	312.00
Total Travel/Transportation[3]				**298.00**			**-**			**739.00**		**1,037.00**
Other Direct Costs	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Production		2	50.00	100.00	1	50.00	50.00	1	50.00	50.00	4	200.00
Shipping		2	25.00	50.00	-	25.00	-	2	25.00	50.00	4	100.00
Total Other Direct Costs				**150.00**			**50.00**			**100.00**		300.00
Total Non-Labor Costs				**448.00**			**50.00**			**3,239.00**		3,737.00
G & A (on Non-Labor Only)				44.80			5.00			323.90		373.70
Total Labor & Non-Labor				**3,932.80**			**1,145.00**			**5,202.90**		**10,280.70**
Profit (on Labor & Non-Labor)				393.28			114.50			520.29		1,028.07
Subtotal Costs				**4,326.08**			**1,259.50**			**5,723.19**		**11,308.77**
Subcontractors	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Phillips County Recorder Fees	LS	-	150.00	-	1	150.00	150.00	-	150.00	-	1	150.00
Legal Fees	LS	-	1,000.00	-	1	1,000.00	1,000.00	-	1,000.00	-	1	1,000.00
Laboratory Analysis	per sample	-	125.00	-	-	125.00	-	7	125.00	875.00	7	875.00
Fence Maintenance & Repair	LS	-	500.00	-	-	500.00	-	1	500.00	500.00	1	500.00
Subtotal Subcontractors[4]				**-**			**1,150.00**			**875.00**		2,025.00
Management fee (on subs only)				-			80.50			61.25		141.75
Total Subcontractors				**-**			**1,230.50**			**936.25**		**2,166.75**
TOTAL				**4,326.08**			**2,490.00**			**6,659.44**		**13,475.52**

Notes:

* 0 for Base Year; 1, 2, 3 for respective option years.

[1] - Labor costs were estimated using professional judgment based on similar projects conducted by AECOM.

[2] - Equipment Costs were based on the AECOM in-house equipment rental rates.

[3] - Travel and Transportation costs estimated using current government per diem rates.

[4] - Phillips County Recorder fees per telephone communication with the Phillips County Recorders office; costs are $15 for the first page and $5 for each additional page; estimate assumes 28 pages. Laboratory costs were based on an estimate from ETC, Inc. Costs for other subcontractors were estimated using professional judgment based on similar projects conducted by AECOM.

[5] - Cost for the annual security inspection and institutional controls O&M is included under Task 03.

TABLE D-3B
PRESENT WORTH (PW) COSTS FOR ALTERNATIVE 3
INSTITUTIONAL CONTROLS WITH GROUNDWATER SAMPLING

Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	5-YEAR REMEDY REVIEW COSTS					
1.00	**5-Year Remedy Review**					
1.01	Year 5	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**
1.02	Year 10	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**

PW for Remedy Review **10 Yrs** **$ 7,008**

Inputs

Inflation Rate **4.00%**

Interest Rate **7.00%**

Year	Inf. Factor	PWF	PW O&M Cost
1	1.0400	0.9346	$0
2	1.0816	0.8734	$0
3	1.1249	0.8163	$0
4	1.1699	0.7629	$0
5	1.2167	0.7130	$3,753
6	1.2653	0.6663	$0
7	1.3159	0.6227	$0
8	1.3686	0.5820	$0
9	1.4233	0.5439	$0
10	1.4802	0.5083	$3,255

TABLE D-3B
PRESENT WORTH (PW) COSTS FOR ALTERNATIVE 3
INSTITUTIONAL CONTROLS WITH GROUNDWATER SAMPLING

Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	SAMPLING AND ANNUAL O&M COSTS					
3.00	**Institutional Controls O&M and Groundwater Monitoring- Years 1 through 10**					
3.01	Year 1	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.02	Year 2	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.03	Year 3	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.04	Year 4	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.05	Year 5	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.06	Year 6	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.07	Year 7	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.08	Year 8	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.09	Year 9	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**
3.10	Year 10	Labor and cost for annual sampling and inspection	Event	6,659.44	1	**$6,659**

PW for Remedy Review — **10 Yrs** — **$ 57,141**

Inputs

Inflation Rate **4.00%**

Interest Rate **7.00%**

Year	Inf. Factor	PWF	PW O&M Cost
1	1.0400	0.9346	$6,473
2	1.0816	0.8734	$6,291
3	1.1249	0.8163	$6,115
4	1.1699	0.7629	$5,944
5	1.2167	0.7130	$5,777
6	1.2653	0.6663	$5,614
7	1.3159	0.6227	$5,457
8	1.3686	0.5820	$5,304
9	1.4233	0.5439	$5,155
10	1.4802	0.5083	$5,010

Alternative 4 – Engineered Barrier with Institutional Controls and Down-Gradient Groundwater Monitoring

Table D-4A
Cost Estimate Summary for Alternative 4
Engineered Barrier
Former Cedar Chemical Facility
Helena – West Helena, Arkansas

Cost Estimate for Alternative 4	**Task**	**01**			**02A**			**03**			**04**			**Total Cost**	
Description		**5-Year Remedy Review Years 5 and 10**			**Institutional Controls Implementation (Year 1)**			**Groundwater Monitoring (Years 1 through 10)[5]**			**Engineered Barrier Implementation (Year 1)**				
	Year *	**5**			**0**			**0**			**1**				
Labor Category	**Units**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Rate**	**Cost**	**Hrs**	**Cost**
Principal	hr	-	155.00	-	-	155.00	-	-	155.00	-	-	155.00	-	-	-
Senior Professional III	hr	-	142.00	-	-	142.00	-	-	142.00	-	-	146.97	-	-	-
Senior Professional II	hr	-	130.00	-	-	130.00	-	-	130.00	-	-	134.55	-	-	-
Senior Professional I - PM	hr	-	120.00	-	-	120.00	-	-	120.00	-	-	124.20	-	-	-
Project Professional II	hr	-	105.00	-	-	105.00	-	-	105.00	-	-	108.68	-	-	-
Project Professional I	hr	8	100.00	800.00	8	100.00	800.00	8	100.00	800.00	40	103.50	4,140.00	64	6,540.00
Staff Professional II	hr	-	85.00	-	-	85.00	-	-	85.00	-	-	87.98	-	-	-
Staff Professional I	hr	-	80.00	-	-	80.00	-	-	80.00	-	-	82.80	-	-	-
Technician III	hr	8	65.00	520.00	2	65.00	130.00	8	65.00	520.00	-	67.28	-	18	1,170.00
Technician II	hr	-	60.00	-	-	60.00	-	-	60.00	-	-	62.10	-	-	-
Technician I	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	56.93	-	-	-
Equipment Operator	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	67.28	-	-	-
CAD/GIS Operator II	hr	4	80.00	320.00	2	80.00	160.00	4	80.00	320.00	-	82.80	-	10	800.00
CAD/GIS Operator I	hr	-	65.00	-	-	65.00	-	-	65.00	-	-	67.28	-	-	-
Draftsman/Illustrator	hr	-	55.00	-	-	55.00	-	-	55.00	-	-	56.93	-	-	-
Project Professional VII	hr	-	100.00	-		100.00	-	-	100.00	-		103.50		-	-
Staff Professional V	hr	-	85.00	-		85.00	-	-	85.00	-		87.98		-	-
Professional III	hr	24	75.00	1,800.00	16	75.00	1,200.00	60	75.00		40	77.63		140	3,000.00
Professional I	hr	-	70.00	-		70.00	-	-	70.00			72.45		-	-
Project Administrator II	hr	-	63.00	-	-	63.00	-	-	63.00	-	-	65.21	-	-	-
Project Administrator I	hr	-	58.00	-	-	58.00	-	-	58.00	-	-	60.03	-	-	-
Total Labor[1]		**44**		**3,440.00**	**28**		**2,290.00**	**80**		**1,640.00**	**80**		**4,140.00**	**232**	**11,510.00**
Field Equipment/Supplies	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
GW Monitoring Equipment & Supplies			2,400.00			2,400.00		1	2,400.00	2,400.00	-	2,400.00	-	1	2,400.00
Total Field Equip/Supplies[2]				**-**			**-**			**2,400.00**			**-**		**2,400.00**
Travel/Transportation	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Airfare	rate	-	500.00	-	-	500.00	-	-	500.00	-	-	500.00	-	-	-
Car Rental/Gas	day	2	75.00	150.00	2	75.00	150.00	3	75.00	225.00	5	75.00	375.00	12	900.00
Lodging	day	1	70.00	70.00	1	70.00	70.00	4	70.00	280.00	4	70.00	280.00	10	700.00
Per diem	day	2	39.00	78.00	2	39.00	78.00	6	39.00	234.00	5	39.00	195.00	15	585.00
Total Travel/Transportation[3]				**298.00**			**298.00**			**739.00**			**850.00**		**2,185.00**
Other Direct Costs	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Production		2	50.00	100.00	1	50.00	50.00	1	50.00	50.00	-	50.00	-	4	200.00
Shipping		2	25.00	50.00	-	25.00	-	2	25.00	50.00	-	25.00	-	4	100.00
Total Other Direct Costs				**150.00**			**50.00**			**100.00**			**-**		300.00
Total Non-Labor Costs				**448.00**			**348.00**			**3,239.00**			**850.00**		4,885.00
G & A (on Non-Labor Only)				44.80			34.80			323.90			85.00		488.50
Total Labor & Non-Labor				**3,932.80**			**2,672.80**			**5,202.90**			**5,075.00**		**16,883.50**
Profit (on Labor & Non-Labor)				393.28			267.28			520.29			507.50		1,688.35
Subtotal Costs				**4,326.08**			**2,940.08**			**5,723.19**			**5,582.50**		**18,571.85**
Subcontractors	**Unit**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Rate**	**Cost**	**Qty**	**Cost**
Phillips County Recorder Fees	LS	-	150.00	-	1	150.00	150.00	-	150.00	-	-	150.00	-	1	150.00
Legal Fees	LS	-	1,000.00	-	1	1,000.00	1,000.00		1,000.00	-		1,000.00	-	1	1,000.00
Laboratory Analysis	sample	-	125.00		-	125.00	-	7	125.00	875.00		125.00	-	7	875.00
Fill	CY	-	15.00	-	-	15.00	-	-	15.00	-	525	15.00	7,875.00	525	7,875.00
Topsoil	CY	-	25.00	-	-	25.00	-	-	25.00	-	210	25.00	5,250.00	210	5,250.00
Hydro seed	Square Foot	-	0.10	-	-	0.10	-	-	0.10	-	12,000	0.10	1,200.00	12,000	1,200.00
Mowing & Trimming	Annual	-	1,000.00	-	-	1,000.00	-	1	1,000.00	1,000.00	-	1,000.00	-	1	1,000.00
Fence Maintenance & Repair	Annual	-	500.00	-	-	500.00	-	1	500.00	500.00	-	500.00	-	1	500.00
Subtotal Subcontractors[4]				**-**			**1,150.00**			**875.00**			**14,325.00**		16,350.00
Management fee (on subs only)				-			80.50			61.25			1,002.75		1,144.50
Total Subcontractors				**-**			**1,230.50**			**936.25**			**15,327.75**		**17,494.50**
TOTAL				**4,326.08**			**4,170.58**			**6,659.44**			**20,910.25**		**36,066.35**

Notes:
* 0 for Base Year; 1, 2, 3 for respective option years.
[1] - Labor costs were estimated using professional judgment based on similar projects conducted by AECOM.
[2] - Equipment Costs were based on the AECOM in-house equipment rental rates.
[3] - Travel and Transportation costs estimated using current government per diem rates.
[4] - Phillips County Recorder fees per telephone communication with the Phillips County Recorders office; costs are $15 for the first page and $5 for each additional page; estimate assumes 28 pages. Laboratory costs were based on an estimate from ETC, Inc. Costs for other subcontractors were estimated using professional judgment based on similar projects conducted by AECOM.
[5] - Cost for the annual security inspection, institutional controls O&M, and engineered barrier O&M is included under Task 03.

TABLE D-4B
PRESENT WORTH (PW) COST FOR ALTERNATIVE 4
ENGINEERED BARRIER WITH INSTITUTIONAL CONTROLS WITH GROUNDWATER SAMPLING
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	5-YEAR REMEDY REVIEW COSTS					
1.00	**5-Year Remedy Review**					
1.01	Year 5	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**
1.02	Year 10	Labor and cost for Site inspection and 5 Year Revie	Event	$4,326	1	**$4,326**

PW for Remedy Review **10 Yrs** **$ 7,008**

Inputs

		Year	Inf. Factor	PWF	PW O&M Cost
Inflation Rate	**4.00%**	**1**	1.0400	0.9346	$0
		2	1.0816	0.8734	$0
Interest Rate	**7.00%**	**3**	1.1249	0.8163	$0
		4	1.1699	0.7629	$0
		5	1.2167	0.7130	$3,753
		6	1.2653	0.6663	$0
		7	1.3159	0.6227	$0
		8	1.3686	0.5820	$0
		9	1.4233	0.5439	$0
		10	1.4802	0.5083	$3,255

TABLE D-4B
PRESENT WORTH (PW) COST FOR ALTERNATIVE 4
ENGINEERED BARRIER WITH INSTITUTIONAL CONTROLS WITH GROUNDWATER SAMPLING

Former Cedar Chemical Facility
Helena - West Helena, Arkansas

ITEM	ITEM DESCRIPTION	BASIS OF COST	UNITS	UNIT COST	QTY	TOTAL
	SAMPLING AND ANNUAL O&M COSTS					
3.00	**Institutional Controls O&M and Groundwater Monitoring- Years 1 through 10**					
3.01	Year 1	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.02	Year 2	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.03	Year 3	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.04	Year 4	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.05	Year 5	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.06	Year 6	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.07	Year 7	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.08	Year 8	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.09	Year 9	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.10	Year 10	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.11	Year 11	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.12	Year 12	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.13	Year 13	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.14	Year 14	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**
3.15	Year 15	Labor and cost for annual sampling and O&M	Event	$6,659.44	1	**$6,659**

PW for Remedy Review **10 Yrs** **$ 57,141**

Inputs

Inflation Rate **4.00%**

Interest Rate **7.00%**

Year	Inf. Factor	PWF	PW O&M Cost
1	1.0400	0.9346	$6,473
2	1.0816	0.8734	$6,291
3	1.1249	0.8163	$6,115
4	1.1699	0.7629	$5,944
5	1.2167	0.7130	$5,777
6	1.2653	0.6663	$5,614
7	1.3159	0.6227	$5,457
8	1.3686	0.5820	$5,304
9	1.4233	0.5439	$5,155
10	1.4802	0.5083	$5,010

Analytical Laboratory Costs

Environmental Testing & Consulting, Inc. Logo-GTW:

www.etcmemphis.com 2790 Whitten Road Memphis, Tennessee 38133 main (901) 213-2400 fax (901) 213-2440

A Laboratory Management Partner

Quote ID **2221**

Project Code AECOM_GREENVILLE

Contact Msa. Doria Cullom

Company AECOM EARTH TECH

Address 10 Patewood Drive
Building VI, Suite 500
Greenville, SC 29615

Telephone (864) 234-3000 0

Fax (864) 234-3069

E-mail Doria,Cullom@aecom.com

Initiated Date 1/28/2009

STM LH 2221LH

Project

Project No.

Parameter	*Method*	*No. of Samples*	*Price Per Sample*	*Price Per Line*
Soil				
TCLP Complete*	1311	1	$695.00	$695.00
Dinoseb	8151	10	$125.00	$1,250.00
Water				
Dinoseb	8151	1	$125.00	$125.00

Quote Total **$2,070.00**

Quote Includes:

Report Level III - Full QC Package

EDD Requirement NONE

Turnaround 10 Working Days

Sample Kit
- ☑ Pre-Preserved / Color Coded Sample Labels
- ☑ Chain-of-Custody Forms
- ☑ Instructions
- ☑ Coolers

Shipping Sample Kit to Client

Return TO: ETC - 2790 Whitten Road - Memphis, TN 38133

Notes

* TCLP 8 RCRA Metals (6010/7470), VOC (8260), SVOC (8270). Pesticides (8081), and Herbicides (8151)

**Next Day TAT 100% mark up
2 Day TAT 50% mark up
3 Day TAT 25% mark up
*** TCLP Complete Rush is 3 to 5 working day due to Pest and Herb mark up 100%

Prices valid for 30 days from date of quotation.

Payment Terms: Net 30 Days

Linda Harper
Sales Team

Sampling Equipment Estimate

EARTH TECH | AECOM

Equipment and Supplies Estimate

REV:10, 3/05/2008 EKO

Job Number : 104336
Task, Subtask / WBS : 08
Client Name : Tyco Safety Products
Date Prepared : 06/18/09
Prepared By :

Equipment Estimate :	$1,879.00
Supplies Estimate :	$457.72
Contingent Expenses :	$0.00
Total Estimate :	$2,336.72

NOTE: RATES ARE COMMERCIAL BILLING RATES, AND YOU SHOULD ASSUME DATE OUT - DATE IN EQUIPMENT BILLING.

	EQUIPMENT	QTYS		RATES			USAGE			BILLING
ASSET #	DESCRIPTION	REQ.	ISU.	DAY	WEEK	MTH.	D	W	M	AMOUNT
10070	EXTINGUISHER FIRE	1	1	1	5	15	3			$3.00
10080	EYEWASH GRAVITY FED	1	1	1	5	15	3			$3.00
15001	CAMERA, DIGITAL, 5 MP	1	1	10	35	100	3			$30.00
25011	ANALYZER MINI RAE 2000, W/10.6 EV LAMP	1	1	60	225	675	3			$180.00
30052	METER WATER QUALITY YSI 556	2	2	80	250	700	3			$480.00
30110	METER TURBIDITY, HF SCIENTIFIC, DRT-15	2	2	25	75	220	3			$150.00
30150	PROBE WATER LEVEL, VARIOUS	2	2	20	60	150	3			$120.00
35030	GENERATOR (4KW, VARIOUS)	2	2	40	120	275	3			$240.00
35100	PUMP PERISTALTIC (12VDC)	1	1	20	70	200	3			$60.00
35120	PUMP SUBMERSIBLE, GNDFS, 2" W/CONTLR	2	2	100	350	700	3			$600.00
45030	BAILERS (2"TEFLON)	1	1	10	15	30	1			$10.00
50130	MACHETE	1	1	1	3	10	3			$3.00
90090	TABLE FOLDING	2	2	0	0	10	3			$0.00
ASSET #	SUPPLIES DESCRIPTION	REQ.	ISU.	COST	UNIT	COMMENTS				AMOUNT
510100	GLASSES SAFETY SUN	2	2	2.85	EA.	REFLECT / TINT				$5.70
510130	GLOVE NITRIL DISP POWDER FREE	2	2	7.97	BX.	100 PER BOX				$15.94
515000	BOTTLE WASH	4	4	8.26	EA.	HDPE				$33.04
515040	BRUSH DECON LONG HANDLE	2	2	8.02	EA.					$16.04
515060	BUCKET 5 GALLON	6	6	4.02	EA.	HDPE				$24.12
515080	BUCKET liD 5 GALLON, TEAR TAB	6	6	1.33	EA.	HDPE				$7.98
515090	CARBOY 5 GALLON W/ SPIGOT	6	6	7.83	EA.	HDPE				$46.98
515100	FOIL ALUMINUM	1	1	68.00	ROLL	18"x500' H-D				$68.00
515110	ISOPROPANOL	1	1	7.80	LTR.	OPTIMA				$7.80
515120	LIQUI-NOX DETERGENT	1	1	12.09	LTR.					$12.09
515140	TOWELS PAPER	3	3	1.41	ROLL					$4.23
515150	WATER DI	10	10	2.35	GAL	IN-HOUSE				$23.50
515170	WATER ORGANIC FREE, IN AMBER GLASS	1	1	18.13	GAL	IN-HOUSE				$18.13
520070	CLOTHS DROP PLASTIC (10'x12')	3	3	2.56	EA.					$7.68
520272	TIES CABLE (6")	30	30	0.07	EA.	100 PER PAK				$2.10
520300	TUBING POLY 3/8"	400	400	0.17	FT.	100' ROLLS				$68.00
525000	BAGGIES ZIP-LOC (12x12 , 4 MIL.)	50	50	0.13	EA.	500 PER CASE				$6.50
525010	BAGGIES ZIP-LOC (12x18,4MIL)	20	20	0.14	EA.	500 PER CASE				$2.80
525050	LABELS NON-HAZ, HAZ WASTE, ETC.	4	4	0.54	EA.					$2.16
525060	PAINT STICKS	1	1	6.30	EA.	YELLOW				$6.30
525080	TAPE CUSTODY SEAL	1	1	3.17	EA.	"STOP"				$3.17
525100	TAPE SHIPPING CLEAR	2	2	2.82	EA.					$5.64
590020	BOOK LOG, HARD CVR	1	1	10.74	EA.	4"x8"				$10.74
590242	DRUM 55 GALLON STEEL OPEN HEAD	2	2	29.54	EA.					$59.08

Construction Cost Estimate for Engineered Barrier

Construction Costs for Engineered Barrier at Site 3
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

Subcontractors	Unit	Qty	Rate	Cost
Fill[1]	CY	525	15.00	7,875
Topsoil[2]	CY	210	25.00	5,250
Hydro seed[3]	Square Foot	12,000	0.10	1,200

Notes:

- All costs were estimated using professional judgment based on similar projects conducted by AECOM.
- Area for engineered barrier emplacement is approximately 11,306 square feet (~0.26 acres)

1. Fill (clay) cost
   Volume = 11,306 square feet * 1 feet thick ~= 420 cubic yards
   Volume needed for compaction = 420 cubic yards * 1.25 = 525 cubic yards
   Cost = 525 cubic yards * $15/cubic yard

2. Topsoil cost
   Volume = 11,306 square feet * 0.5 feet thick ~= 210 cubic yards
   Cost = 210 cubic yards * $25/cubic yard

3. Hydro seed cost
   Area = 11,306 square feet; assumed ~12,000 for estimating
   Cost = 12,000 square feet * $0.10 per square foot

APPENDIX E

HELP MODEL RESULTS FOR ALTERNATIVE 4

HELP Model Input – Climate Data

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data,
and Information Service

Climatography of the United States No. 20 1971-2000

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: HELENA, AR **COOP ID: 033242**

Climate Division: AR 6 **NWS Call Sign:** **Elevation: 195 Feet** **Lat: 34˚31N** **Lon: 90˚35W**

Temperature (˚F)																					
	Mean (1)			Extremes										Degree Days (1) Base Temp 65		Mean Number of Days (3)					
Month	Daily Max	Daily Min	Mean	Highest Daily(2)	Year	Day	Highest Month(1) Mean	Year	Lowest Daily(2)	Year	Day	Lowest Month(1) Mean	Year	Heating	Cooling	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
Jan	48.9	29.8	39.4	79	1975	30	47.0	1990	-3+	1966	30	27.7	1977	795	0	.0	.0	14.2	3.4	19.3	.3
Feb	54.5	33.9	44.2	81	1962	13	51.8	1976	-3	1951	2	33.0	1978	582	0	.0	.0	18.1	1.8	12.9	.0
Mar	63.9	42.5	53.2	86	1963	31	58.2	1974	11	1965	20	47.3	1980	374	8	.0	.0	27.1	.1	4.4	.0
Apr	73.6	50.7	62.2	95	1987	22	68.8	1981	28+	1966	5	54.7	1983	142	57	.0	.2	29.6	.0	.5	.0
May	82.0	60.0	71.0	98	1977	31	76.3	1987	38	1969	11	63.9	1976	30	217	.0	3.2	31.0	.0	.0	.0
Jun	89.8	67.8	78.8	106	1954	28	83.1	1998	44	1966	1	73.2	1974	0	414	.1	14.7	30.0	.0	.0	.0
Jul	93.0	71.9	82.5	107	1980	18	87.1	1980	49	1967	15	79.7	1972	0	541	1.0	22.5	31.0	.0	.0	.0
Aug	91.6	70.0	80.8	107	2000	31	86.7	2000	48	1967	28	76.8	1992	0	491	1.2	19.5	31.0	.0	.0	.0
Sep	85.6	63.0	74.3	104+	1954	4	79.9	1998	30	1967	30	67.4	1974	10	289	.2	9.0	30.0	.0	.0	.0
Oct	76.2	51.0	63.6	96	1998	1	69.7	1971	25	1965	25	57.9	1976	117	73	.0	.8	30.9	.0	.2	.0
Nov	63.2	41.2	52.2	88	1988	5	57.6	1985	13+	1976	29	43.6	1976	391	8	.0	.0	25.4	.1	5.6	.0
Dec	53.1	33.1	43.1	80	1982	3	51.1	1971	-4	1983	25	31.5	1983	679	0	.0	.0	18.6	1.5	15.2	.2
Ann	73.0	51.2	62.1	107+	Aug 2000	31	87.1	Jul 1980	-4	Dec 1983	25	27.7	Jan 1977	3120	2098	2.5	69.9	316.9	6.9	58.1	.5

+ Also occurred on an earlier date(s)

@ Denotes mean number of days greater than 0 but less than .05

Complete documentation available from: www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

(1) From the 1971-2000 Monthly Normals

(2) Derived from station's available digital record: 1948-2001

(3) Derived from 1971-2000 serially complete daily data

Issue Date: February 2004

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data,
and Information Service

Climatography of the United States No. 20 1971-2000

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: HELENA, AR **COOP ID: 033242**

Climate Division: AR 6 **NWS Call Sign:** **Elevation: 195 Feet** **Lat: 34°31N** **Lon: 90°35W**

Precipitation (inches)

	Precipitation Totals								Mean Number of Days (3)				Precipitation Probabilities (1) Probability that the monthly/annual precipitation will be equal to or less than the indicated amount										
	Means/ Medians(1)		Extremes						Daily Precipitation				Monthly/Annual Precipitation vs Probability Levels These values were determined from the incomplete gamma distribution										
Month	Mean	Med-ian	Highest Daily(2)	Year	Day	Highest Monthly(1)	Year	Lowest Monthly(1)	Year	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
Jan	4.60	3.94	4.27	1952	27	9.48	1989	.49	1986	9.6	7.1	3.3	1.4	1.30	1.74	2.40	2.97	3.53	4.12	4.77	5.53	6.52	8.08	9.53
Feb	4.08	3.80	5.55	1966	10	9.36	1990	.88	1972	8.5	6.1	2.9	1.2	1.01	1.39	1.99	2.51	3.04	3.59	4.21	4.94	5.90	7.42	8.84
Mar	5.35	5.00	3.40	1983	5	10.65	1980	2.22	1974	10.0	7.5	3.8	1.9	2.08	2.57	3.28	3.87	4.42	4.99	5.60	6.31	7.21	8.59	9.85
Apr	5.36	5.01	4.05	1955	13	18.91	1991	1.46	1989	8.0	6.4	3.5	1.8	1.38	1.88	2.66	3.35	4.03	4.74	5.54	6.48	7.71	9.65	11.47
May	5.67	5.03	7.60	1974	15	14.12	1974	1.19	1992	9.4	6.8	3.5	1.8	1.43	1.97	2.79	3.52	4.24	5.00	5.85	6.85	8.17	10.24	12.18
Jun	4.76	4.50	6.91	1980	24	11.89	1974	.10	1988	7.7	6.1	2.8	1.4	1.00	1.44	2.14	2.77	3.41	4.09	4.86	5.78	7.00	8.94	10.78
Jul	3.74	3.00	6.00	1980	22	10.34	1989	.84	1991	6.6	5.1	2.3	1.0	.80	1.15	1.69	2.19	2.69	3.22	3.82	4.54	5.49	7.01	8.44
Aug	2.74	2.39	5.70	1982	14	6.74	1982	.00+	2000	5.5	4.1	1.8	.7	.00	.44	.98	1.42	1.85	2.31	2.82	3.42	4.24	5.55	6.80
Sep	3.16	2.59	5.09	1959	27	9.38	1977	.17	2000	6.5	4.5	2.1	.9	.28	.50	.92	1.36	1.84	2.38	3.03	3.85	4.97	6.84	8.67
Oct	3.69	3.59	5.71	1984	7	14.02	1984	.10	2000	5.7	4.7	2.5	1.3	.62	.94	1.48	1.99	2.51	3.07	3.72	4.51	5.56	7.26	8.88
Nov	5.51	4.86	4.31	1983	23	17.52	1987	.89	1998	8.4	6.5	3.6	2.0	1.09	1.59	2.40	3.14	3.89	4.70	5.61	6.71	8.16	10.49	12.70
Dec	5.39	4.12	5.75	1978	4	17.27	1982	.74	1980	8.5	6.4	3.2	1.8	1.11	1.60	2.39	3.12	3.84	4.62	5.50	6.56	7.96	10.20	12.31
Ann	54.05	55.44	7.60	May 1974	15	18.91	Apr 1991	.00+	Aug 2000	94.4	71.3	35.3	17.2	35.78	39.22	43.68	47.10	50.16	53.15	56.24	59.69	63.89	70.04	75.40

+ Also occurred on an earlier date(s)
# Denotes amounts of a trace
@ Denotes mean number of days greater than 0 but less than .05
** Statistics not computed because less than six years out of thirty had measurable precipitation

(1) From the 1971-2000 Monthly Normals
(2) Derived from station's available digital record: 1948-2001
(3) Derived from 1971-2000 serially complete daily data
Complete documentation available from:
www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

Notes

a. The monthly means are simple arithmetic averages computed by summing the monthly values for the period 1971-2000 and dividing by thirty. Prior to averaging, the data are adjusted if necessary to compensate for data quality issues, station moves or changes in station reporting practices. Missing months are replaced by estimates based on neighboring stations.

b. The median is defined as the middle value in an ordered set of values. The median is being provided for the snow and precipitation elements because the mean can be a misleading value for precipitation normals.

c. Only observed validated values were used to select the extreme daily values.

d. Extreme monthly temperature/precipitation means were selected from the monthly normals data.
Monthly snow extremes were calculated from daily values quality controlled to be consistent with the Snow Climatology.

e. Degree Days were derived using the same techniques as the 1971-2000 normals.
Compete documentation for the 1971-2000 Normals is available on the internet from:
www.ncdc.noaa.gov/oa/climate/normals/usnormals.html

f. Mean "number of days statistics" for temperature and precipitation were calculated from a serially complete daily data set .
Documentation of the serially complete data set is available from the link below:

g. Snowfall and snow depth statistics were derived from the Snow Climatology.
Documentation for the Snow Climatology project is available from the link under references.

Data Sources for Tables

Several different data sources were used to create the Clim20 climate summaries. In some cases the daily extremes appear inconsistent with the monthly extremes and or the mean number of days statistics. For example, a high daily extreme value may not be reflected in the highest monthly value or the mean number of days threshold that is less than and equal to the extreme value. Some of these difference are caused by different periods of record. Daily extremes are derived from the station's entire period of record while the serial data and normals data were are for the 1971-2000 period. Therefore extremes observed before 1971 would not be included in the 1971-2000 normals or the 1971-2000 serial daily data set. Inconsistencies can also occur when monthly values are adjusted to reflect the current observing conditions or were replaced during the 1971-2000 Monthly Normals processing and are not reconciled with the Summary of the Day data.

a. Temperature/ Precipitation Tables
1. 1971-2000 Monthly Normals
2. Cooperative Summary of the Day
3. National Weather Service station records
4. 1971-2000 serially complete daily data

b. Degree Day Table
1. Monthly and Annual Heating and Cooling Degree Days Normals to Selected Bases derived from 1971-2000 Monthly Normals
2. Daily Normal Growing Degree Units to Selected Base Temperatures derived from 1971-2000 serially complete daily data

c. Snow Tables
1. Snow Climatology
2. Cooperative Summary of the Day

d. Freeze Data Table
1971-2000 serially complete daily data

References

U.S. Climate Normals 1971-2000, www.ncdc.noaa.gov/normals.html

U.S. Climate Normals 1971-2000-Products Clim20, www.ncdc.noaa.gov/oa/climate/normals/usnormalsprods.html

Snow Climatology Project Description, www.ncdc.noaa.gov/oa/climate/monitoring/snowclim/mainpage.html

Eischeid, J. K., P. Pasteris, H. F. Diaz, M. Plantico, and N. Lott, 2000: Creating a serially complete, national daily time series of temperature and precipitation for the Western United States. J. Appl. Meteorol., 39, 1580-1591,
www1.ncdc.noaa.gov/pub/data/special/ serialcomplete_jam_0900.pdf

Climatography of the United States NO. 84, 1971-2000

Daily Normals of

Temperature, Precipitation, and Heating and Cooling Degree Days

(includes monthly tables for precipitation probability and quintiles)

Station Name, State:	HELENA, AR	Station Number:	033242

Latitude:	343°1'	Longitude:	-903°5'	Elevation:	640ft	Climate Division:	06

December

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	57	37	47	18	0	0.19
2	57	36	47	18	0	0.19
3	57	36	46	19	0	0.19
4	56	36	46	19	0	0.19
5	56	36	46	19	0	0.19
6	56	35	46	19	0	0.18
7	55	35	45	20	0	0.18
8	55	35	45	20	0	0.18
9	55	34	45	20	0	0.18
10	55	34	44	21	0	0.18
11	54	34	44	21	0	0.18
12	54	34	44	21	0	0.18
13	54	34	44	21	0	0.18
14	53	33	43	22	0	0.18
15	53	33	43	22	0	0.17
16	53	33	43	22	0	0.17
17	53	33	43	22	0	0.17
18	52	32	42	23	0	0.17
19	52	32	42	23	0	0.17
20	52	32	42	23	0	0.17
21	52	32	42	23	0	0.17
22	51	32	42	23	0	0.17
23	51	32	41	24	0	0.17
24	51	31	41	24	0	0.17
25	51	31	41	24	0	0.16
26	51	31	41	24	0	0.16
27	50	31	41	24	0	0.16
28	50	31	40	25	0	0.16
29	50	31	40	25	0	0.16
30	50	30	40	25	0	0.16
31	50	30	40	25	0	0.16
MNTH:	53.1	33.1	43.1	679	0	5.39

January

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	49	30	40	25	0	0.16
2	49	30	40	25	0	0.16
3	49	30	40	25	0	0.16
4	49	30	39	26	0	0.16
5	49	30	39	26	0	0.16
6	49	30	39	26	0	0.15
7	49	30	39	26	0	0.15
8	49	30	39	26	0	0.15
9	49	30	39	26	0	0.15
10	48	30	39	26	0	0.15
11	48	29	39	26	0	0.15
12	48	29	39	26	0	0.15
13	48	29	39	26	0	0.15
14	48	29	39	26	0	0.15
15	48	29	39	26	0	0.15
16	48	29	39	26	0	0.15
17	48	29	39	26	0	0.15
18	48	29	39	26	0	0.15
19	49	30	39	26	0	0.15
20	49	30	39	26	0	0.15
21	49	30	39	26	0	0.15
22	49	30	39	26	0	0.14
23	49	30	39	26	0	0.14
24	49	30	40	26	0	0.14
25	49	30	40	25	0	0.14
26	49	30	40	25	0	0.14
27	50	30	40	25	0	0.14
28	50	30	40	25	0	0.14
29	50	30	40	25	0	0.14
30	50	31	40	25	0	0.14
31	51	31	41	24	0	0.14
MNTH:	48.9	29.8	39.4	795	0	4.60
Winter	52.2	32.3	42.2	2056	0	14.07
Annual	73.0	51.2	62.1	3120	2098	54.05

February

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	51	31	41	24	0	0.14
2	51	31	41	24	0	0.14
3	51	31	41	24	0	0.14
4	51	32	42	24	0	0.14
5	52	32	42	23	0	0.14
6	52	32	42	23	0	0.14
7	52	32	42	23	0	0.14
8	53	32	42	23	0	0.14
9	53	32	43	22	0	0.14
10	53	33	43	22	0	0.14
11	53	33	43	22	0	0.14
12	54	33	43	22	0	0.14
13	54	33	44	21	0	0.14
14	54	34	44	21	0	0.14
15	55	34	44	21	0	0.14
16	55	34	44	20	0	0.15
17	55	34	45	20	0	0.15
18	55	35	45	20	0	0.15
19	56	35	45	20	0	0.15
20	56	35	46	19	0	0.15
21	56	35	46	19	0	0.15
22	57	36	46	19	0	0.15
23	57	36	47	18	0	0.15
24	57	36	47	18	0	0.15
25	58	37	47	18	0	0.15
26	58	37	47	18	0	0.16
27	58	37	48	17	0	0.16
28	59	38	48	17	0	0.16
MNTH:	54.5	33.9	44.2	582	0	4.08

Climatography of the United States NO. 84, 1971-2000

Daily Normals of

Temperature, Precipitation, and Heating and Cooling Degree Days

(includes monthly tables for precipitation probability and quintiles)

Station Name, State:	HELENA, AR	Station Number:	033242

Latitude: 343°1' Longitude: -903°5' Elevation: 640ft Climate Division: 06

March

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	59	38	48	17	0	0.16
2	59	38	49	16	0	0.16
3	60	39	49	16	0	0.16
4	60	39	49	16	0	0.16
5	60	39	50	15	0	0.16
6	61	40	50	15	0	0.16
7	61	40	50	15	0	0.17
8	61	40	51	14	0	0.17
9	62	41	51	14	0	0.17
10	62	41	51	14	0	0.17
11	62	41	52	13	0	0.17
12	63	41	52	13	0	0.17
13	63	42	52	13	0	0.17
14	63	42	53	13	0	0.17
15	64	42	53	12	0	0.17
16	64	43	53	12	0	0.17
17	64	43	54	12	0	0.17
18	65	43	54	11	0	0.18
19	65	43	54	11	0	0.18
20	65	44	55	11	0	0.18
21	66	44	55	11	0	0.18
22	66	44	55	10	0	0.18
23	66	45	55	10	0	0.18
24	66	45	56	10	1	0.18
25	67	45	56	9	1	0.18
26	67	45	56	9	1	0.18
27	67	46	57	9	1	0.18
28	68	46	57	9	1	0.18
29	68	46	57	8	1	0.18
30	68	46	57	8	1	0.18
31	69	47	58	8	1	0.18
MNTH:	63.9	42.5	53.2	374	8	5.35

April

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	69	47	58	8	1	0.18
2	70	47	58	7	1	0.18
3	70	47	59	7	1	0.18
4	70	48	59	7	1	0.18
5	70	48	59	7	1	0.18
6	71	48	59	7	1	0.18
7	71	48	60	6	1	0.17
8	71	49	60	6	1	0.17
9	72	49	60	6	1	0.17
10	72	49	61	6	1	0.17
11	72	49	61	5	1	0.18
12	73	50	61	5	1	0.18
13	73	50	61	5	1	0.18
14	73	50	62	5	2	0.18
15	74	50	62	5	2	0.18
16	74	51	62	4	2	0.18
17	74	51	63	4	2	0.18
18	74	51	63	4	2	0.18
19	75	52	63	4	2	0.18
20	75	52	64	4	2	0.18
21	75	52	64	4	2	0.18
22	76	52	64	3	2	0.18
23	76	53	64	3	3	0.18
24	76	53	65	3	3	0.18
25	76	53	65	3	3	0.18
26	77	54	65	3	3	0.18
27	77	54	66	3	3	0.18
28	77	54	66	3	3	0.18
29	77	55	66	3	4	0.18
30	78	55	66	2	4	0.18
MNTH:	73.6	50.7	62.2	142	57	5.36
Spring	73.2	51.1	62.1	546	282	16.38
Annual	73.0	51.2	62.1	3120	2098	54.05

May

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	78	55	67	2	4	0.18
2	78	56	67	2	4	0.18
3	78	56	67	2	4	0.18
4	79	56	68	2	5	0.18
5	79	57	68	2	5	0.18
6	79	57	68	2	5	0.18
7	80	57	68	2	5	0.19
8	80	58	69	2	5	0.19
9	80	58	69	1	5	0.19
10	80	58	69	1	6	0.19
11	81	59	70	1	6	0.19
12	81	59	70	1	6	0.19
13	81	59	70	1	6	0.19
14	81	60	70	1	6	0.19
15	82	60	71	1	7	0.19
16	82	60	71	1	7	0.18
17	82	60	71	1	7	0.18
18	83	61	72	1	7	0.18
19	83	61	72	1	8	0.18
20	83	61	72	1	8	0.18
21	83	62	72	1	8	0.18
22	84	62	73	1	8	0.18
23	84	62	73	0	9	0.18
24	84	62	73	0	9	0.18
25	84	63	74	0	9	0.18
26	85	63	74	0	9	0.18
27	85	63	74	0	9	0.18
28	85	63	74	0	10	0.18
29	86	64	75	0	10	0.18
30	86	64	75	0	10	0.18
31	86	64	75	0	10	0.18
MNTH:	82.0	60.0	71.0	30	217	5.67

Climatography of the United States NO. 84, 1971-2000

Daily Normals of

Temperature, Precipitation, and Heating and Cooling Degree Days

(includes monthly tables for precipitation probability and quintiles)

Station Name, State:	HELENA, AR	Station Number:	033242

Latitude: 343°1' Longitude: -903°5' Elevation: 640ft Climate Division: 06

June

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	87	65	76	0	11	0.17
2	87	65	76	0	11	0.17
3	87	65	76	0	11	0.17
4	87	65	76	0	11	0.17
5	88	66	77	0	12	0.17
6	88	66	77	0	12	0.17
7	88	66	77	0	12	0.17
8	88	66	77	0	12	0.17
9	89	66	78	0	13	0.17
10	89	67	78	0	13	0.17
11	89	67	78	0	13	0.16
12	89	67	78	0	13	0.16
13	90	67	78	0	14	0.16
14	90	68	79	0	14	0.16
15	90	68	79	0	14	0.16
16	90	68	79	0	14	0.16
17	90	68	79	0	14	0.16
18	90	68	79	0	14	0.16
19	91	69	80	0	15	0.16
20	91	69	80	0	15	0.15
21	91	69	80	0	15	0.15
22	91	69	80	0	15	0.15
23	91	69	80	0	15	0.15
24	91	70	81	0	15	0.15
25	92	70	81	0	16	0.15
26	92	70	81	0	16	0.15
27	92	70	81	0	16	0.15
28	92	70	81	0	16	0.14
29	92	70	81	0	16	0.14
30	92	71	81	0	16	0.14
MNTH:	89.8	67.8	78.8	0	414	4.76

July

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	92	71	81	0	16	0.14
2	93	71	82	0	16	0.14
3	93	71	82	0	17	0.14
4	93	71	82	0	17	0.14
5	93	72	82	0	17	0.14
6	93	72	82	0	17	0.13
7	93	72	82	0	17	0.13
8	93	72	82	0	17	0.13
9	93	72	82	0	17	0.13
10	93	72	82	0	17	0.13
11	93	72	82	0	17	0.13
12	93	72	82	0	17	0.13
13	93	72	83	0	17	0.13
14	93	72	83	0	17	0.12
15	93	72	83	0	18	0.12
16	93	72	83	0	18	0.12
17	93	72	83	0	18	0.12
18	93	72	83	0	18	0.12
19	93	72	83	0	18	0.12
20	93	72	83	0	18	0.12
21	93	73	83	0	18	0.11
22	93	72	83	0	18	0.11
23	93	72	83	0	18	0.11
24	93	72	83	0	18	0.11
25	93	72	83	0	18	0.11
26	93	72	83	0	18	0.11
27	93	72	83	0	18	0.10
28	93	72	83	0	18	0.10
29	93	72	83	0	18	0.10
30	93	72	82	0	18	0.10
31	93	72	82	0	17	0.10
MNTH:	93.0	71.9	82.5	0	541	3.74
Summer	91.5	69.9	80.7	0	1446	11.24
Annual	73.0	51.2	62.1	3120	2098	54.05

August

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	93	72	83	0	18	0.10
2	93	72	82	0	17	0.10
3	93	72	82	0	17	0.09
4	93	72	82	0	17	0.09
5	93	71	82	0	17	0.09
6	93	71	82	0	17	0.09
7	93	71	82	0	17	0.09
8	93	71	82	0	17	0.09
9	93	71	82	0	17	0.09
10	92	71	82	0	17	0.09
11	92	71	82	0	17	0.09
12	92	71	82	0	17	0.09
13	92	71	81	0	16	0.09
14	92	70	81	0	16	0.08
15	92	70	81	0	16	0.08
16	92	70	81	0	16	0.08
17	92	70	81	0	16	0.08
18	92	70	81	0	16	0.08
19	91	70	81	0	16	0.08
20	91	70	80	0	16	0.08
21	91	69	80	0	15	0.09
22	91	69	80	0	15	0.09
23	91	69	80	0	15	0.09
24	91	69	80	0	15	0.09
25	90	69	80	0	15	0.09
26	90	68	79	0	14	0.09
27	90	68	79	0	14	0.09
28	90	68	79	0	14	0.09
29	90	68	79	0	14	0.09
30	90	68	79	0	14	0.09
31	89	68	78	0	13	0.09
MNTH:	91.6	70.0	80.8	0	491	2.74

Climatography of the United States NO. 84, 1971-2000

Daily Normals of

Temperature, Precipitation, and Heating and Cooling Degree Days

(includes monthly tables for precipitation probability and quintiles)

Station Name, State:	HELENA, AR	Station Number:	033242

Latitude: 343°1' Longitude: -903°5' Elevation: 640ft Climate Division: 06

September

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	89	67	78	0	13	0.09
2	89	67	78	0	13	0.09
3	89	67	78	0	13	0.10
4	88	67	78	0	12	0.10
5	88	66	77	0	12	0.10
6	88	66	77	0	12	0.10
7	88	66	77	0	12	0.10
8	87	66	77	0	12	0.10
9	87	65	76	0	11	0.10
10	87	65	76	0	11	0.10
11	87	65	76	0	11	0.10
12	87	64	76	0	11	0.10
13	86	64	75	0	10	0.11
14	86	64	75	0	10	0.11
15	86	64	75	0	10	0.11
16	86	63	74	0	10	0.11
17	85	63	74	0	9	0.11
18	85	62	74	0	9	0.11
19	85	62	73	0	9	0.11
20	85	62	73	0	9	0.11
21	84	61	73	1	8	0.11
22	84	61	72	1	8	0.11
23	84	61	72	1	8	0.11
24	83	60	72	1	7	0.11
25	83	60	71	1	7	0.11
26	83	59	71	1	7	0.11
27	83	59	71	1	7	0.11
28	82	58	70	1	6	0.11
29	82	58	70	1	6	0.11
30	82	58	70	1	6	0.11
MNTH:	85.6	63.0	74.3	10	289	3.16

October

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	82	57	69	1	5	0.11
2	81	57	69	1	5	0.11
3	81	56	69	1	5	0.11
4	81	56	68	1	5	0.10
5	80	55	68	2	4	0.10
6	80	55	67	2	4	0.10
7	80	54	67	2	4	0.11
8	79	54	67	2	4	0.11
9	79	54	66	2	3	0.11
10	79	53	66	2	3	0.11
11	78	53	66	2	3	0.11
12	78	52	65	3	3	0.11
13	78	52	65	3	2	0.11
14	77	51	64	3	2	0.11
15	77	51	64	3	2	0.11
16	76	51	64	3	2	0.11
17	76	50	63	4	2	0.11
18	76	50	63	4	2	0.12
19	75	50	62	4	1	0.12
20	75	49	62	4	1	0.12
21	74	49	62	5	1	0.12
22	74	49	61	5	1	0.12
23	74	48	61	5	1	0.13
24	73	48	61	6	1	0.13
25	73	48	60	6	1	0.13
26	72	47	60	6	1	0.14
27	72	47	59	6	1	0.14
28	71	47	59	7	1	0.14
29	71	46	59	7	1	0.14
30	70	46	58	7	1	0.15
31	70	46	58	8	1	0.15
MNTH:	76.2	51.0	63.6	117	73	3.69
Autumn	75.0	51.7	63.4	518	370	12.36
Annual	73.0	51.2	62.1	3120	2098	54.05

November

DATE	MAX	MIN	AVG	HDD	CDD	PRCP
1	69	45	57	8	1	0.16
2	69	45	57	8	1	0.16
3	69	45	57	9	1	0.16
4	68	45	56	9	1	0.17
5	68	44	56	9	1	0.17
6	67	44	56	10	1	0.17
7	67	44	55	10	1	0.17
8	66	43	55	11	1	0.18
9	66	43	54	11	0	0.18
10	65	43	54	11	0	0.18
11	65	43	54	12	0	0.18
12	64	42	53	12	0	0.19
13	64	42	53	12	0	0.19
14	64	42	53	13	0	0.19
15	63	41	52	13	0	0.19
16	63	41	52	13	0	0.19
17	62	41	52	14	0	0.19
18	62	40	51	14	0	0.19
19	62	40	51	14	0	0.19
20	61	40	51	15	0	0.19
21	61	40	50	15	0	0.19
22	60	39	50	15	0	0.19
23	60	39	49	16	0	0.20
24	60	39	49	16	0	0.20
25	59	38	49	16	0	0.19
26	59	38	49	16	0	0.19
27	59	38	48	17	0	0.19
28	58	38	48	17	0	0.19
29	58	37	48	17	0	0.19
30	58	37	47	18	0	0.19
MNTH:	63.2	41.2	52.2	391	8	5.51

Climatography of the United States NO. 84, 1971-2000

Precipitation Probability and Quintiles

Station Name, State:	HELENA, AR	Station Number:	033242

Latitude: 343°1' Longitude: -903°5' Elevation: 640ft Climate Division: 06

Probability that the monthly precipitation will be equal to or less than the indicated amount

Monthly Precipitation (inches)

Probability	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.005	0.55	0.38	1.13	0.54	0.56	0.34	0.27	0.00	0.04	0.17	0.35	0.36	27.92
0.010	0.71	0.51	1.34	0.71	0.73	0.46	0.37	0.00	0.08	0.25	0.49	0.50	29.90
0.050	1.30	1.01	2.08	1.38	1.43	1.00	0.80	0.00	0.28	0.62	1.09	1.11	35.78
0.100	1.74	1.39	2.57	1.88	1.97	1.44	1.15	0.44	0.50	0.94	1.59	1.60	39.22
0.200	2.40	1.99	3.28	2.66	2.79	2.14	1.69	0.98	0.92	1.48	2.40	2.39	43.68
0.300	2.97	2.51	3.87	3.35	3.52	2.77	2.19	1.42	1.36	1.99	3.14	3.12	47.10
0.400	3.53	3.04	4.42	4.03	4.24	3.41	2.69	1.85	1.84	2.51	3.89	3.84	50.16
0.500	4.12	3.59	4.99	4.74	5.00	4.09	3.22	2.31	2.38	3.07	4.70	4.62	53.15
0.600	4.77	4.21	5.60	5.54	5.85	4.86	3.82	2.82	3.03	3.72	5.61	5.50	56.24
0.700	5.53	4.94	6.31	6.48	6.85	5.78	4.54	3.42	3.85	4.51	6.71	6.56	59.69
0.800	6.52	5.90	7.21	7.71	8.17	7.00	5.49	4.24	4.97	5.56	8.16	7.96	63.89
0.900	8.08	7.42	8.59	9.65	10.24	8.94	7.01	5.55	6.84	7.26	10.49	10.20	70.04
0.950	9.53	8.84	9.85	11.47	12.18	10.78	8.44	6.80	8.67	8.88	12.70	12.31	75.40
0.990	12.66	11.94	12.52	15.42	16.42	14.83	11.58	9.56	12.86	12.49	17.57	16.98	86.16
0.995	13.95	13.23	13.60	17.05	18.16	16.51	12.88	10.71	14.65	14.01	19.60	18.92	90.34

Precipitation Quintiles (inches)

Level	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0<	0.49	0.88	2.22	1.46	1.19	0.10	0.84	0.00	0.17	0.10	0.89	0.74
1	0.49	0.88	2.22	1.46	1.19	0.10	0.84	0.00	0.17	0.10	0.89	0.74
	2.40	1.99	3.28	2.66	2.79	2.14	1.69	0.98	0.92	1.48	2.40	2.39
2	2.41	2.00	3.29	2.67	2.80	2.15	1.70	0.99	0.93	1.49	2.41	2.40
	3.53	3.04	4.42	4.03	4.24	3.41	2.69	1.85	1.84	2.51	3.89	3.84
3	3.54	3.05	4.43	4.04	4.25	3.42	2.70	1.86	1.85	2.52	3.90	3.85
	4.77	4.21	5.60	5.54	5.85	4.86	3.82	2.82	3.03	3.72	5.61	5.50
4	4.78	4.22	5.61	5.55	5.86	4.87	3.83	2.83	3.04	3.73	5.62	5.51
	6.52	5.90	7.21	7.71	8.17	7.00	5.49	4.24	4.97	5.56	8.16	7.96
5	6.53	5.91	7.22	7.72	8.18	7.01	5.50	4.25	4.98	5.57	8.17	7.97
	9.48	9.36	10.65	18.91	14.12	11.89	10.34	6.74	9.38	14.02	17.52	17.27
6>	9.48	9.36	10.65	18.91	14.12	11.89	10.34	6.74	9.38	14.02	17.52	17.27

(These values were determined from the incomplete Gamma Distribution)

This page was dynamically generated on Thu Jun 25 11:54:59 EDT 2009 via http://www5.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl

HELP Model Output

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP\HPRECIP.D4
TEMPERATURE DATA FILE:       C:\HELP\HTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP\HSOLRAD.D13
EVAPOTRANSPIRATION DATA:     C:\HELP\HEVAP.D11
SOIL AND DESIGN DATA FILE:   c:\help\CEDARSD.D10
OUTPUT DATA FILE:            C:\HELP\CEDAR.OUT


TIME:  21:42     DATE:   6/28/2009


******************************************************************************

     TITLE:  Tyco Cedar Chemical

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   5
           THICKNESS                  =      6.00   INCHES
           POROSITY                   =      0.4570 VOL/VOL
           FIELD CAPACITY             =      0.1310 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4570 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.100000005000E-02 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                   LAYER  2
                                   --------

                      TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.4510 VOL/VOL
           FIELD CAPACITY             =      0.4190 VOL/VOL
           WILTING POINT              =      0.3320 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.4510 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.999999972000E-09 CM/SEC


                GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                ----------------------------------------
```

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF  2.%
          AND A SLOPE LENGTH OF   50. FEET.

SCS RUNOFF CURVE NUMBER            =     68.10
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      0.260  ACRES
EVAPORATIVE ZONE DEPTH             =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      2.742  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      2.742  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.348  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =      8.154  INCHES
TOTAL INITIAL WATER                =      8.154  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          HELENA                ARIZONA

     STATION LATITUDE                        =  34.52 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   2.00
     START OF GROWING SEASON (JULIAN DATE)   =     67
     END OF GROWING SEASON (JULIAN DATE)     =    312
     EVAPORATIVE ZONE DEPTH                  =   6.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   8.00 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  69.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  70.00 %


 NOTE:  PRECIPITATION DATA FOR     HELENA              ARKANSAS
          WAS ENTERED FROM AN ASCII DATA FILE.


 NOTE:  TEMPERATURE DATA FOR     HELENA              ARKANSAS
          WAS ENTERED FROM AN ASCII DATA FILE.


 NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    LITTLE ROCK         ARKANSAS
            AND STATION LATITUDE  =  34.52 DEGREES
```

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*******************************************************************************
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MONTHLY TOTALS (MM) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	116.8	103.6	135.9	136.1	144.0	120.9
	95.0	69.6	80.3	93.7	140.0	136.9
RUNOFF	76.60	57.71	59.04	36.67	9.63	0.00
	0.00	0.00	0.00	0.00	77.46	95.77
EVAPOTRANSPIRATION	41.39	46.26	75.24	99.68	146.92	158.79
	102.33	69.64	75.26	57.95	46.06	40.14
PERCOLATION/LEAKAGE THROUGH	0.040	0.036	0.040	0.039	0.038	0.032
LAYER 2	0.001	0.000	0.000	0.012	0.038	0.040

MONTHLY SUMMARIES FOR DAILY HEADS (CM)

AVERAGE DAILY HEAD ON	15.116	15.054	14.930	14.821	13.044	7.237
TOP OF LAYER 2	0.034	0.000	0.000	1.333	14.372	15.139
STD. DEVIATION OF DAILY	0.015	0.083	0.260	0.296	1.358	2.561
HEAD ON TOP OF LAYER 2	0.163	0.000	0.000	2.272	1.734	0.012

ANNUAL TOTALS FOR YEAR 1

	MM	CU. METERS	PERCENT
PRECIPITATION	1372.87	1444.540	100.00
RUNOFF	412.876	434.431	30.07
EVAPOTRANSPIRATION	959.676	1009.777	69.90
PERC./LEAKAGE THROUGH LAYER 2	0.316694	0.333	0.02
AVG. HEAD ON TOP OF LAYER 2	92.5679		
CHANGE IN WATER STORAGE	0.000	0.000	0.00
SOIL WATER AT START OF YEAR	207.109	217.922	
SOIL WATER AT END OF YEAR	207.109	217.922	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0005	-0.001	0.00

AVERAGE MONTHLY VALUES (MM) FOR YEARS 1 THROUGH 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	116.84	103.63	135.89	136.14	144.02	120.90
	95.00	69.60	80.26	93.73	139.95	136.91
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	76.597	57.711	59.042	36.667	9.625	0.000
	0.000	0.000	0.000	0.000	77.463	95.771
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	41.387	46.265	75.245	99.684	146.923	158.789
	102.328	69.641	75.263	57.951	46.064	40.138

```
  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

 PERCOLATION/LEAKAGE THROUGH LAYER  2
 ------------------------------------
  TOTALS                 0.0401   0.0361   0.0399   0.0385   0.0382   0.0321
                         0.0013   0.0000   0.0000   0.0122   0.0381   0.0401

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

-------------------------------------------------------------------------------
                 AVERAGES OF MONTHLY AVERAGED DAILY HEADS (CM)
-------------------------------------------------------------------------------

 DAILY AVERAGE HEAD ON TOP OF LAYER  2
 -------------------------------------
  AVERAGES              15.1157  15.0541  14.9298  14.8213  13.0444   7.2371
                         0.0344   0.0000   0.0000   1.3334  14.3724  15.1390

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH    1
-------------------------------------------------------------------------------
                                      MM             CU. METERS     PERCENT
                              --------------------   -----------   ---------
 PRECIPITATION               1372.87    (   0.000)      1444.5     100.00

 RUNOFF                       412.876   (  0.0000)       434.43     30.074

 EVAPOTRANSPIRATION           959.676   (  0.0000)      1009.78     69.903

 PERCOLATION/LEAKAGE THROUGH    0.31669 (  0.00000)        0.333     0.02307
   LAYER  2

 AVERAGE HEAD ON TOP           92.568 (    0.000)
   OF LAYER  2

 CHANGE IN WATER STORAGE        0.000   (  0.0000)         0.00      0.000

*******************************************************************************


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               PEAK DAILY VALUES FOR YEARS    1 THROUGH    1
   ------------------------------------------------------------------------
                                                     (MM)       (CU. METERS)
                                                  ----------    ------------
      PRECIPITATION                                  5.08            5.345

      RUNOFF                                         4.635           4.8770

      PERCOLATION/LEAKAGE THROUGH LAYER  2           0.001296        0.00136

      AVERAGE HEAD ON TOP OF LAYER  2              152.400

      SNOW WATER                                     0.00            0.0000

      MAXIMUM VEG. SOIL WATER (VOL/VOL)                      0.4570

      MINIMUM VEG. SOIL WATER (VOL/VOL)                      0.0710

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FINAL WATER STORAGE AT END OF YEAR 1

LAYER	(CM)	(VOL/VOL)
1	6.9647	0.4570
2	13.7465	0.4510
SNOW WATER	0.000	

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APPENDIX F

REVISED REMEDIAL GOAL OPTION FOR ALTERNATIVE 4

Table F-1
Derivation of Revised Dilution Attenuation Factor (DAF) for Alternative 4 - Engineered Barrier
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

Dilution Attenuation Factor (Equation B-14, USEPA 2002):

$$\boxed{DAF = 1 + \frac{K * i * d}{I * L}}$$

Where:

Parameter	Definition	Original Value	Original Units	Value	Units	Reference
K	aquifer hydraulic conductivity	1.90E-02	cm/sec	5.99E+03	m/yr	Average value for the Alluvial Aquifer based on step drawdown tests (Table 5, FI, AMEC Geomatrix, February 2009)
i	hydraulic gradient	0.00097	ft/ft	0.00097	m/m	Calculated for the Site 3 area based on July 2008 Alluvial Aquifer Potentiometric Map (Fig 10, AMEC Geomatrix, Feb 2009)
I	infiltration rate	3.17E-01	cm/yr	**3.17E-03**	m/yr	Calculated infiltration rate
d	mixing zone depth	0.78	m	0.78	m	Calculated using Equation B-15, USEPA 2002 below
L	source length parallel to groundwater flow	24	ft/ft	7.32E+00	m	Calculated from surfer figure showing exceedances of industrial MSL (620 ppm) - uses historic concentration of dinoseb (13,000 ppm) at 3 SB-6
d_a	aquifer thickness	101	feet	3.08E+01	m	Log for 4 MW-4 (EnSafe, 1996) which is just SE of Site 3 and nearest deep boring to Site 3; (EnSafe 2001 RA uses 34.8 m as d_a)

Table F-1
Derivation of Revised Dilution Attenuation Factor (DAF) for Alternative 4 - Engineered Barrier
Former Cedar Chemical Facility
Helena - West Helena, Arkansas

Estimation of Mixing Zone Depth (Equation B-15, USEPA 2002):

$$\boxed{d = \left(0.0112L^2\right)^{0.5} + d_a\left(1 - \exp\left[\frac{(-L*I)}{(K*i*d_a)}\right]\right)}$$

d =	**0.78**	meters
DAF =	**196.28**	unitless

References:

AMEC Geomatrix 2009. Facility Investigation Report, Cedar Chemical Corporation, Helena-West Helena, Arkansas. February.

EnSafe, Inc., 1996. Facility Investigation, Cedar Chemical Company. (Phase I through III). June 28.

United States Environmental Protection Agency (USEPA) 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2009. Regional Screening Levels for Chemical Contaminants at Superfund Sites. USEPA Region 6 Soil Screening Level website accessed at http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search.

Table F-2

Values Used For Calculating a Revised Remedial Goal Option (RGO) for a Resident Exposed to Groundwater from a Potable Water Well in the Alluvial Aquifer

Alternative 4 - Engineered Barrier

Former Cedar Chemical Facility

Helena - West Helena, Arkansas

RGO (mg/kg) = $C_w \times [\ K_d + (\ (\theta_w + (\theta_a \times H')\ )\ /\ \rho_b\ )\ ]$

Based on the EPA Region 6 Risk-Based Medium Screening Level of 0.037 mg/L

Where:

Cw = target groundwater concentration (DAF x MSL) =	7.262	mg/L	Calculated
DAF =	**196.28**	unitless	See Table F-1
MSL =	0.037	mg/L	USEPA 2009
Kd = soil/water partition coefficient (Koc x foc) =	7.08	L/kg	Calculated
Koc = organic carbon partition coefficient =	3540	L/kg	ORNL 2009
foc = organic carbon content of soil =	0.002	kg/kg	USEPA 2002
θw = water-filled soil porosity =	0.3	L/L	USEPA 2002
θa = air-filled soil porosity (1 - [ρb/ρs] - θw) =	0.13	unitless	Calculated
ρb = dry soil bulk density =	1.5	kg/L	USEPA 2002
ρs = soil particle density =	2.65	kg/L	USEPA 2002
H' = Henry's law constant =	0.00000186	unitless	ORNL 2009

Risk-Based RGO (mg/kg) = 52.9

References:

Oak Ridge National Laboratory (ORNL) 2009. Risk Assessment Information System accessed online at http://rais.ornl.gov/cgi-bin/tox/TOX_select?select=chem.

United States Environmental Protection Agency (USEPA) 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Washington, DC. Office of Emergency and Remedial Response.

USEPA 2006. 2006 Edition of the Drinking Water Standards and Health Advisories. Washington, DC. Office of Water.

USEPA 2008. Region 6 Human Health Medium-Specific Screening Level Table.